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ECONOMICS OF FORAGE PRODUCTION

IN THE MOUNTAIN MEADOW AREAS OF COLORADO

A Progress Report

AGRICULTURAL RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE

in cooperation with

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PREFACE

How can Colorado ranchers get more from their meadows? An equally important question is, "How can they increase production from their ranches most economically?" Along with ranchers, agronomists and soil scientists have been investigating the first of these questions since 1950. Considerable progress has been made in learning how to irrigate and fertilize mountain meadows to get higher yields of hay and hay of higher quality. The research on which this progress report is based was addressed to the second question.

This study was initiated by J. L. Paschal, formerly with the Farm Economics Research Division, ARS, and particular thanks are expressed for his early work. M. L. Upchurch, of the Farm Economics Research Division, ARS, directed and supervised the study. The author is indebted to scientists, particularly to Forrest Willhite, Hayden Rouse, and Frank Viets, of the Soil and Water Conservation Research Division, ARS, U. S. Department of Agriculture, and to scientists in the Department of Agronomy, Colorado State University, for help in interpreting the data used. Thanks are due also to the ranchers who provided their time and access to their records.

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ECONOMICS OF FORAGE PRODUCTION IN THE MOUNTAIN MEADOW AREAS OF COLORADO

A Progress Report

by

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SUMMARY

Production of hay is a major cost of ranching in the mountain meadow areas of Colorado. Declining yields per acre, and the relatively high feed requirements per animal unit in these areas that result from the rather long winter feeding period, justify special scrutiny of the management practices and the economics of producing hay on these ranches.

Recent research work in the Colorado mountain meadow areas has shown that certain management practices can be used to increase the quantity or change the quality of hay produced on the average meadow.

The results of feeding trials carried on in conjunction with this research and economic data gathered from ranch operators reveal that certain of the management practices have relatively favorable input-output ratios. Under proper irrigation, the most promising practices are simple to carry out and are capable of increasing the efficiency of the ranch enterprise. If the meadows are not too rough, if their soil profile is favorable, responses to certain management practices exist.

Ranch operators should consider three types of hay for their winter feeding programs: (1) The base feed for the main herd; (2) the base feed for the weaner calves; and (3) if the base feed is of too low quality, supplemental feed, mainly for weaners. In addition, some operators may have potential increases in forage production, which would increase the size of operation. Economies associated with increase in scale of operation, in some instances may overcome certain diseconomies associated with forage production.

Generally, the quality of the hay produced is satisfactory for the main herd. Thus, the problem here is one of producing additional quantities of hay at less than the average market price. Applying 40 pounds of available nitrogen annually will produce 0. 50 ton per acre of additional hay at a cost of less than $20. 00 per ton. Two other practices, the seeding of legumes into the existing sod, and applying phosphate fertilizer to seeded sod, are economical also.

Most ranchers produce some hay that is above minimum requirements for weaner calves. But frequently, this quality better hay is intermingled with other hay or is not favorably located; therefore, the operator may want to raise better than average quality hay on specific fields as feed for weaners. The best way to be sure that the desired quality is obtained is to use the two-cut harvest system. Here again, the application of phosphate fertilizer in conjunction with seeding legumes into the sod or the application of 40 pounds of nitrogen fertilizer are the least costly methods of obtaining this type of hay. The additional costs incurred with these practices are more than offset by the value of the increase in quality and quantity of hay produced.

If hay containing a high percentage of protein - superhay - is desired as a supplement to lower quality hay, the most profitable practices will involve a two-cut harvest system alone or in conjunction with high rates of nitrogen application - more than 320 pounds. While these nitrogen application rates indicate very high costs per acre, the number of acres required is relatively small. On a typical Colorado ranch, not more than 3 acres would need to be so treated.

The practices cited as economically feasible are based on the premise that the practices either reduce the average cost or that the increased value of the hay exceeds the increase in the costs. The analysis does not take into account other benefits that might accrue to an increase in the quantity or quality of mountain meadow hay. Associated economies that might be involved would be the ability of the operator to increase the size of his herd and thereby reduce his average cost of operation per cow-unit, the possible increase in weight of animals caused by feeding the animals a better ration, or reduction in use of summer range that might accompany increased production from meadows. Additional studies will be required to analyze these possibilities.

If the proper conditions exist, many ranchers in the mountain meadow areas of Colorado can increase production of hay from their meadows economically by: (1) Applying approximately 50 pounds of nitrogen fertilizer per acre; (2) periodically seeding adapted legumes into the existing sod; (3) or both. If commercial feed supplements or hay of better quality is needed to obtain the desired winter gains on weaner calves, probably it

would be economical to harvest sufficient quantities of hay under the two-cut harvest system, along with one of the following:

1. Apply approximately 50 pounds of nitrogen fertilizer per acre;

2. Apply between 300 and 400 pounds of nitrogen fertilizer per acre (at the most, 1 acre per 45 weaner calves would need to be so treated to provide a supplement for hay of very low quality, 6.5 percent crude protein or less);

3. Seed adapted legumes periodically into the existing sod and apply phosphate fertilizer on areas adapted to this practice.

INTRODUCTION

Most ranchers in the mountain meadow areas of Colorado can use more hay. Improved irrigation and other practices will increase yields, but how can additional feed be obtained most economically? What increases in the volume and quality of hay can be expected from improved management practices? What costs are associated with these improved management practices, and what is the value of this increased production? Answers to these questions are needed to determine the most economical management of the feed supply on typical mountain meadow ranches.

The study reported here applies generally to the mountain meadow area of Colorado. (See figure 1.) The area is rugged; it lies mainly above 6,000 feet in elevation, and it has a short, cool, growing season. For the most part, its meadow soils are shallow, and in general, its irrigation water supply is sufficient or even excessive. The short, cool, growing season limits the farming activities of the area to the raising of grass or grass-legume mixed hays.

Since 1950, the Soil and Water Conservation Research Division, Agriculture Research Service, U. S. Department of Agriculture, the Experiment Station of Colorado State University, and rancher groups have worked together through a common research program to find techniques that will increase the quality and quantity of forage produced from mountain meadows. Five general management practices considered by these researchers were: (1) Changing the timing and quantity of the irrigation water applied; (2) applying nitrogen or phosphate fertilizers; (3) using a two-cut system of harvesting rather than the usual one-cut system; (4) timing of harvest; and (5) changing the composition of the sward.

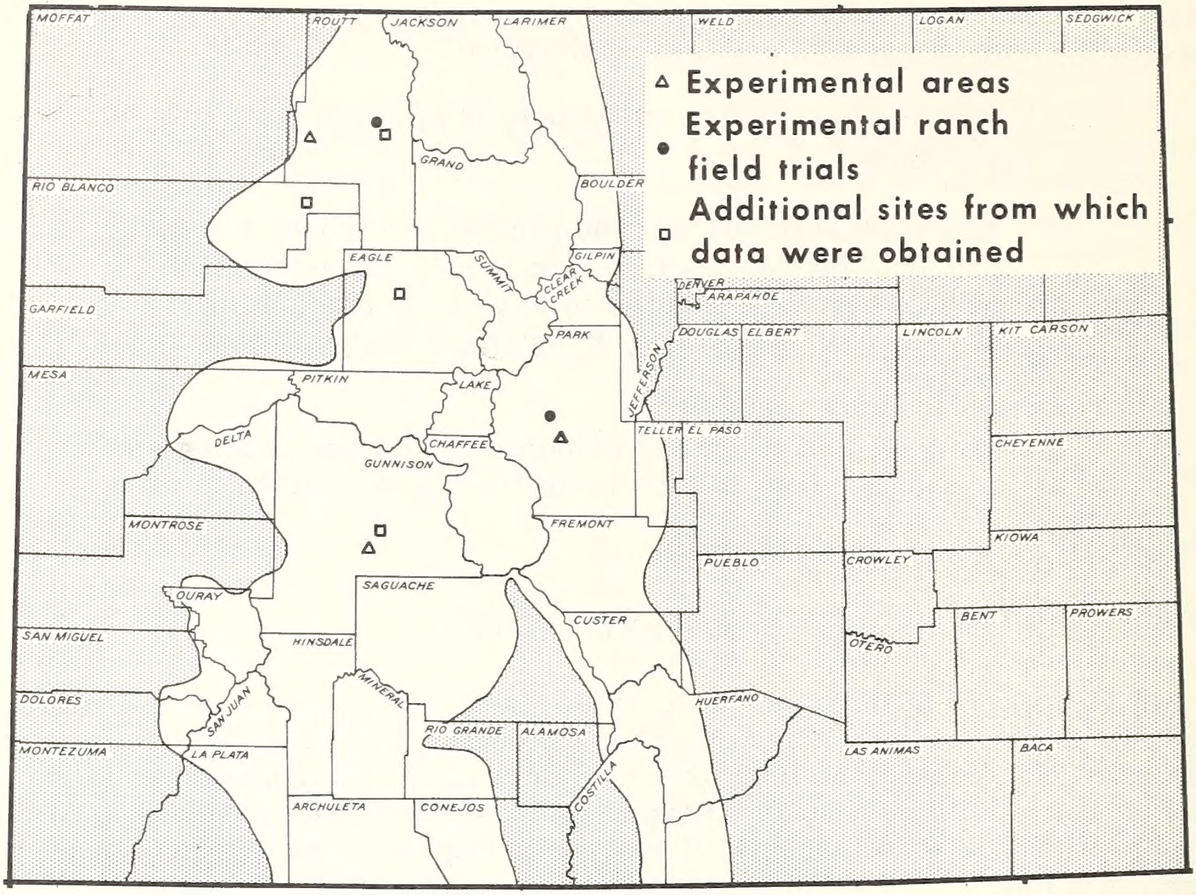

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Figure 1. Mountain meadow area of Colorado

They found that unless reasonably good irrigation practices were followed, maximum benefits from these practices could not be obtained. Ideal irrigation means that the meadow is given a light irrigation approximately every week or two throughout the growing season. The amount of water applied and the frequency of application depend upon the soil profile, its water-retention abilities, temperature, humidity, stage of growth, and other factors. Analysis of the most economical irrigation practices warrants special attention. For phases of the study reported here, we assume that reasonably good, intermittent irrigation is practical and will be carried on.

The study on which this publication is based was intended to summarize results of research on selected management practices and to analyze these results from an economic viewpoint. To do this, monetary values need to be established for hays of various quality and costs of harvesting.

VOLUME AND QUALITY OF HAY

Several Federal, State, and private agencies have worked together for several years to learn what increases in the volume and quality of hay may be expected from (1) timing of harvest; (2) fertilization; (3) use of two-cut harvest system; and (4) changing the composition of the sward. Application of fertilizer was the management practice most thoroughly examined by these groups and data relative to this practice are both more detailed and more numerous than data for the other three practices. However, significant data have been gathered and analyses published on the other practices.

Time of Harvest

The stage of maturity of forage growth at time of harvesting affects the volume and quality of hay produced. If the meadow is cut twice during the season, the time of harvesting affects the crude protein content more than it does the volume of hay. Normally, if hay is to be harvested only once, the greatest volume is obtained when the hay is cut at the latest possible date, consistent with weather risk, or when the major specie (or species) is approaching full bloom, whichever occurs first.

In his work at Gunnison, Colo., in 1951 and 1952, Miller 1/ analyzed for crude protein content hays cut from experimental plots at different dates in the same field. His data show that both earlier harvest and fertilizer increase the protein content of hay while later harvest increases yields. Both protein content and yields were higher for the fertilized than for the unfertilized plots. The data presented in table 1 indicates that with each week's delay in harvest between early June and late August, the percentage of crude protein decreases by approximately 0.38 percent for unfertilized hay, and by 0.94 percent for hay fertilized with 160 pounds of available nitrogen. By late August, the crude protein contents of the fertilized and unfertilized hay are approximately the same.

In 1950 and 1952, Willhite and others 2/ collected hay samples from 13 different ranches. When analyzed for crude protein content, these samples

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1/ Miller, D. E. Plant Growth of High Altitude Hay Meadows as Affected Stage of Maturity and Fertilization. Unpublished Thesis, Colorado A & M College, tables 1, 2, 7, and 8, pp. 111-112, 117-118. 1953.

2/ Willhite, F. M., Rouse, H. K., and Miller, D. E. Use of Beef Cattle Feeding Data in Evaluating Mountain Meadow Management Practices. Jour. Anim. Sci. 13(4):808-816. 1954.

Table 1. - Production and crude protein content of hay, with no fertilizer, and with 160 pounds of nitrogen added annually, cut at specified harvest dates, experiment plots, Gunnison, Colo., 1951 and 1952.

NOT FERTILIZED

Date	Yield per acre	Percentage of crude protein	Date	Yield per acre	Percentage of crude protein
	Tons	Percent		Tons	Percent
Hay harvest 1951:			Hay harvest 1952:		
June 12	1.15	11.50	June 17	1.11	14.31
June 25	1.97	10.44	June 30	2.03	13.13
July 18	2.22	10.38	July 12	2.42	11.31
August 2	3.25	11.75	July 28	2.65	10.44
August 18	2.89	9.94	August 13	3.52	10.00
August 27	3.19	9.19	August 22	2.87	8.75
L. S. D. (0.05) between dates	.36	1.00	L. S. D. (0.05) between dates	.38	.94
L. S. D. (0.01) between dates	.47	1.31	L. S. D. (0.01) between dates	.51	1.25

FERTILIZED

Date	Yield per acre	Percentage of crude protein	Date	Yield per acre	Percentage of crude protein
Hay harvest 1951:			Hay harvest 1952:		
June 12	1.45	16.88	June 17	1.58	21.06
June 25	2.72	15.75	June 30	2.76	17.44
July 18	3.49	10.69	July 12	3.22	14.94
August 2	3.95	11.06	July 28	4.21	12.25
August 8	4.54	10.13	August 13	4.72	10.94
August 27	5.36	9.00	August 22	5.28	9.25
L. S. D. (0.05) between dates	.36	1.00	L. S. D. (0.05) between dates	.38	.94
L. S. D. (0.01) between dates	.47	1.31	L. S. D. (0.01) between dates	.51	1.00

See Miller, D. E., footnote 1, page 5.

showed the same general relationship - the later the date of harvest, the lower was the crude protein content. The calculated weekly decline in crude protein content averaged 0.63 percent, or approximately two-thirds greater than was found by Miller. Willhite's data were obtained from 13 different ranches (30 observations). These hays were not all harvested in the same way; the sward composition and irrigation practices differed; and the sampling was done by 13 different people. Therefore, a greater variation in crude protein content than occurred in Miller's experiment would be expected from Willhite's observations. But it is likely that the decrease of 0.38 percent for unfertilized hay and 0.94 percent for fertilized hay as found by Miller would be more generally applicable than the decrease observed by Willhite.

Maturity of the species in the sward, rather than the calendar date, is the major determinant of protein content. One method of obtaining high-protein hay, at least in limited quantities, is to harvest at an early date. Ranchers usually harvest their meadows only once and as late in the season as possible, whether the meadows are fertilized or unfertilized. This practice produces the greatest volume of hay, although its protein content is lower than for hay cut earlier.

Fertilization

Results from large numbers of fertilizer experiments have shown that production responds to applications of fertilizer in a general pattern. When soil is low in a particular nutrient or nutrients, the relationship between nutrients added and crop yields usually follows a curve as illustrated in figure 2.

The first part of this curve (segment A) is an area in which the crop yield increases with each additional unit of fertilizer but contributes less to the yield than the preceding unit. Also, if enough fertilizer is applied, a point may be reached at which an actual decrease in the total yield is associated with increased applications of fertilizer (segment B). In general, work on production responses of hay to applications of nitrogen and phosphorus by Willhite and Rouse has been with that segment of the response curve labeled "A," in which total yield was increased with each additional unit of fertilizer, but with each unit contributing less to yield than the preceding unit.

In 1952, Willhite and Rouse conducted an experiment on seven mountain meadow ranches, in which 200 pounds of available phosphate and varying quantities of nitrogen were applied to individual meadows in an effort to learn the response of these meadows to nitrogen and phosphate under normal ranch

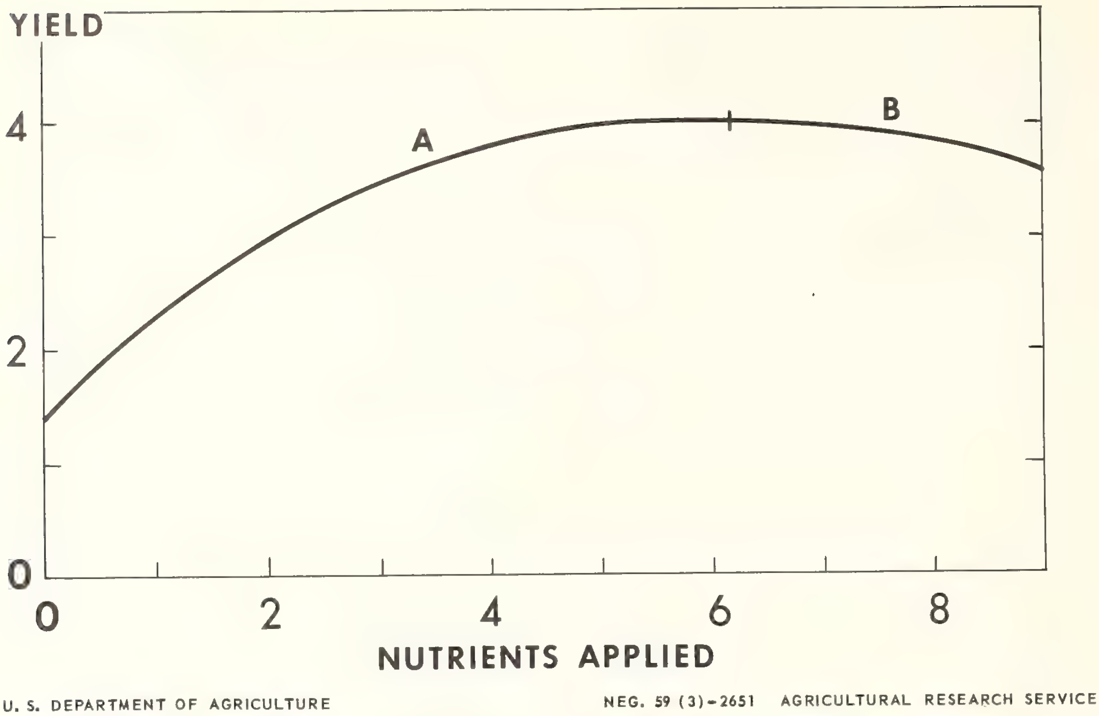

Figure 2. Model of yield response curve.

operations (table 2). Production of hay per acre increased until 240 pounds of nitrogen had been applied. The larger amounts applied - 320 and 640 pounds - did not actually increase production of hay per acre, but the crude protein content of the hay increased at these higher rates of nitrogen. Utilizing the research work of Spillman 3/ and others, a curve was fitted to the yield data relative to production responses to nitrogen. The estimated values obtained are included in table 2 under the column headed "Calculated yield."

The equation used in determining the calculated yield is based on a large number of experiments, and in conjunction with the data obtained by Willhite and Rouse, it gives a better idea of expected yields from varying nitrogen applications than does the arithmetic average of the original data. For this reason, the calculated yields rather than the actual averages are used in later discussions.

While calculated or averaged yields give one a better idea as to what one can expect on an average, they do not necessarily reflect what one will obtain on any specific meadow or in a particular year. Figure 3 approximates the individual ranch production response curves to nitrogen applications that are found in table 2. It is evident from these production response curves that there is no one most profitable nitrogen application rate applicable to all 7 ranches.

3/ Spillman, W. J. Use of the Exponential Yield Curve in Fertilizer Experiments. U. S. Dept. Agr. Tech. Bul. 348, 67 pp. 1933.

Table 2. - Yield response of native hay to 200 pounds of phosphate and specified nitrogen applications, experimental plots, seven mountain meadow ranches, Colorado, 1952

Fertilizer treatment	Yield per acre on ranch -							Average yield per acre	Average crude protein content	Calculated yield 1/
	1	2	3	4	5	6	7			
	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Percent	Tons
None----------	2.00	3.89	2.36	2.12	2.20	1.46	0.71	2.11	10.13	2.08
40 lbs. N------	2.94	3.98	2.83	2.16	2.39	2.08	.99	2.49	9.95	2.59
80 lbs. N------	3.34	4.55	3.19	2.42	3.34	2.48	1.36	2.95	10.71	2.87
160 lbs. N-----	3.33	4.13	3.58	3.06	3.99	2.29	1.43	3.11	12.46	3.11
240 lbs. N-----	3.26	4.03	3.22	2.89	3.99	3.10	1.99	3.21	13.34	3.19
320 lbs. N-----	3.01	3.75	3.47	3.23	4.17	2.68	2.08	3.20	14.30	3.21
640 lbs. N-----	3.27	3.95	3.49	2.89	3.83	3.01	1.87	3.19	16.26	3.22
200 lbs. P_2O_5 -	2.34	3.86	2.43	2.48	2.10	2.17	.68	2.29	10.68	---

1/ See Spillman, W. J., footnote 3, page 8.

Willhite, F. M., Rouse, H. K., and Miller, D. E. Colorado Mountain Meadow Research, Colo. Agr. Expt. Sta. Gen. Ser. Paper 562, p. 48, 1954, except as otherwise stated.

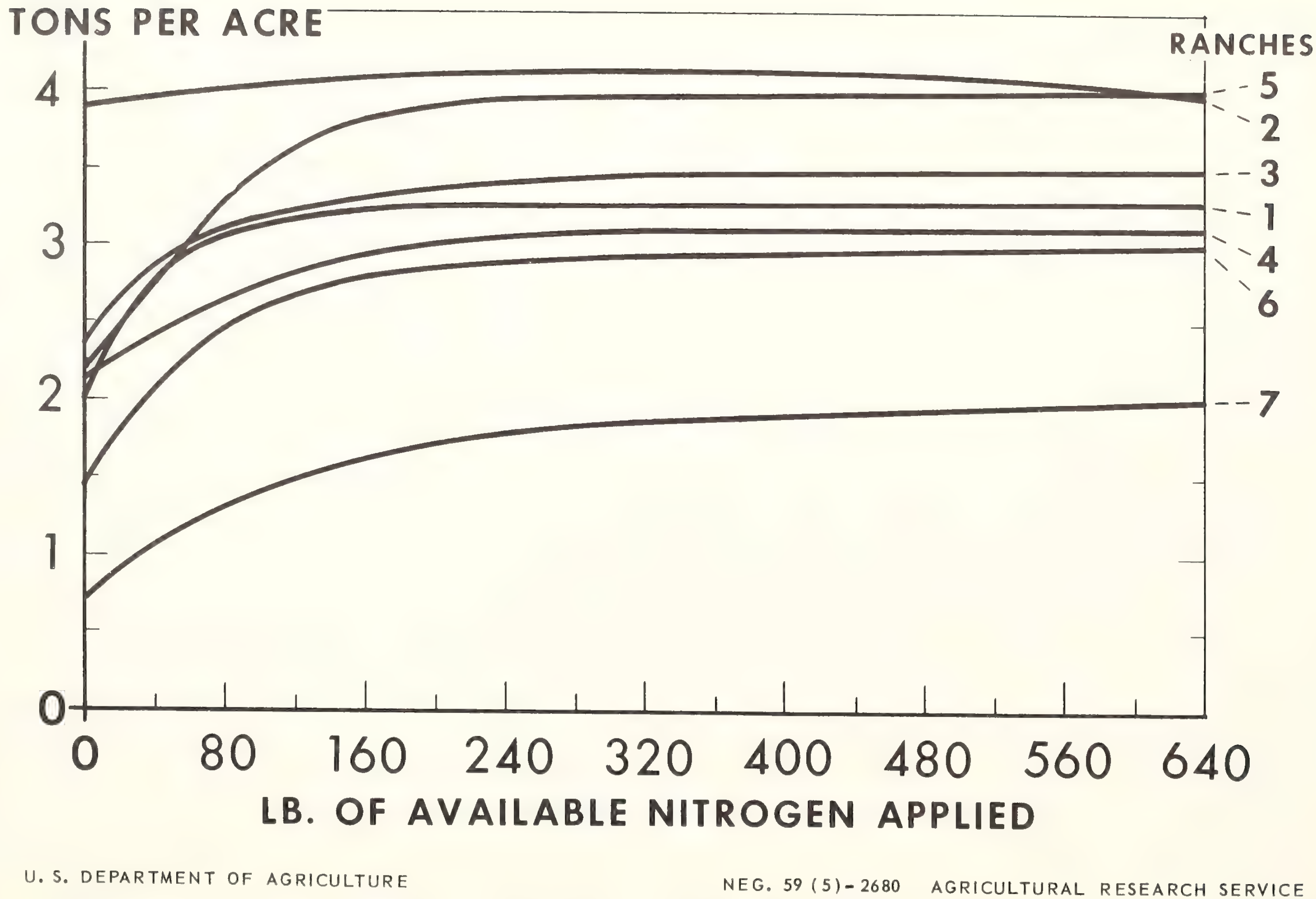

Figure 3. Estimated responses in production of hay to application of nitrogen fertilizer on seven Colorado ranches in 1952.

To illustrate this, if we utilize the information presented in the appendix under Guide for Determining Rate of Application of Nitrogen Fertilizer to Produce Regular Hay, in determining the most profitable rate of nitrogen application for each of the 7 ranches, we find these rates for each ranch to be:

Ranch	Pounds of Nitrogen
1	50
2	0
3	66
4	0
5	108
6	78
7	48

These rates assume that hay is valued at $20.00 per ton and the cost of buying and applying the nitrogen is $0.15 per pound. When the calculated curve is analyzed with the same procedure used, its most profitable rate is 50 pounds of available nitrogen. Therefore, two of the ranches (1 and 7) have responses similar to the average, while two ranches' responses - those from 2 and 4 were so low that it would be unprofitable to apply any nitrogen. Ranches 3, 5, and 6 could apply more nitrogen than we find for the calculated curve. Any analysis based on the calculated yield of table 2 will be applicable only to meadows whose response curve is essentially the same. In our subsequent analysis, we use this calculated yield, but the reader is reminded that the response curve for any meadow will deviate somewhat from these production responses.

More hay is produced per pound of nitrogen at the lower rates of application. The increased yield associated with the first application of nitrogen is greater than that associated with any later application. That is, it takes a greater amount of nitrogen to obtain a given increase in yield as more and more nitrogen is applied. For instance, the first 40 pounds of nitrogen increased the calculated yield 0.51 ton per acre, but it took 120 pounds (160 pounds total) of nitrogen to increase the yield an additional 0.52 ton per acre.

One qualification of the calculated yield is that the average production of hay from mountain meadows of Colorado in 1952, as reported by the State Statistician, was 1 ton per acre. This average includes a considerable acreage of low-producing bottom or swampland on which the practices under consideration are not applicable. The average production of lands amenable to the improved management practices under consideration is undoubtedly higher than 1 ton per acre but probably not as high as the 2.11 tons average for the experimental group. This means that, when fertilizer is applied to

the "average" mountain meadow in Colorado, the results will vary somewhat from the calculated value presented here. Within reasonable limits, the increased production associated with nitrogen applications will approximate what can be expected from an average "good" mountain meadow in Colorado.

These experiments demonstrate also that application of phosphate fertilizer will increase production on mountain meadows. As shown in table 2, the average yield on all ranches was increased by 0.18 ton in the year 1952. The effects of phosphate fertilizer, unlike nitrogen, are not exhausted rapidly. They may influence yields over a period of time - usually a minimum of 5 years when 200 pounds of P_2O_5 are applied. This would mean that a rancher could reasonably expect an average increase of 0.9 ton of hay and an increase in crude protein content of approximately 0.5 percent for the 5 years. Data from other experiments in Colorado are consistent with these results.

Results of experiments on station plots frequently show higher yields than those obtained by ranchers. On the Blackstock experimental plots, near Gunnison, Colo., nitrogen response averages approximately 11 percent more than the average response ranchers received. This figure is almost the same as that obtained by Cooper and Sawyer when they compared the results from station experiments with off-station trials. On the average, the difference in yields was 10.69 percent; it varied from 14.50 to 5.38 percent. 4/ Data from experimental plots may be used as a basis for economic analysis, if corrections in expected yields and responses to fertilizer and other practices are made. Corrections of this kind have been made wherever experimental data are used in this analysis. The data in table 2, however, were not corrected because these data are not from experimental plots.

Two-Cut System of Harvesting

This method of harvesting is not usually practiced by mountain meadow ranchers. In most instances, the purpose of the system is primarily to increase the protein content of hay when the effect on yield is of secondary importance. Willhite and Rouse 5/ measured the results of a two-cut versus a one-cut system of harvesting on the Blackstock Station (table 3).

4/ Cooper, C. S. and Sawyer, W. A. Fertilization of Mountain Meadows in Eastern Oregon. Jour. Range Mangt. 8:20-22. 1955.

5/ Willhite, F. M., and Rouse, H. K. Colorado Mountain Meadow Annual Reports, 1952 and 1953. Fort Collins, U. S. Agricultural Research Service, Soil and Water Conservation Branch. (Mimeographed.)

Table 3. - Production and quality of hay under specified fertility treatments on native sod, two-cut versus one-cut system of harvesting, Blackstock Experimental area, Colorado, 1950-53

PRODUCTION

Method of harvesting	Fertility treatment 1/						Average
	1	2	3	4	5	6	
	Tons	Tons	Tons	Tons	Tons	Tons	Tons
Two-cut 2/---	2.56	2.78	2.95	3.15	3.60	3.70	3.12
One-cut------	2.42	2.42	2.86	3.14	3.47	3.72	3.00
Difference--	.14	.36	.09	.01	.13	-.02	.12

CRUDE PROTEIN CONTENT

	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Two-cut 2/---	15.5	14.9	14.5	13.8	13.6	13.5	14.3
One-cut------	10.6	10.2	8.9	8.0	9.3	8.9	9.3
Difference--	4.9	4.7	5.6	5.8	4.3	4.6	5.0

1/ Fertility treatments:
- (1) - no treatment.
- (2) - single application of 200 pounds of P_2O_5 in 1950.
- (3) - annual application of 40 pounds of available nitrogen.
- (4) - annual application of 80 pounds of available nitrogen.
- (5) - annual application of 160 pounds of available nitrogen.
- (6) - combination of 2 and 5.

2/ Average crude protein percentage of the 2 cuttings: The first or early harvest would be approximately 1 percent less than average, and the second harvest would be about 1 percent more.

See Willhite, F. M., and Rouse, H. K., footnote 5, page 12.

Yields of hay were not affected greatly by the harvesting system, although production responses from the two-cut are greatest when an application of phosphate fertilizer accompanies this practice. Low rates of nitrogen application, when combined with the two-cut system, give approximately the same production per acre as the single-cut with comparable applications of nitrogen.

The highest percentage of crude protein was obtained under the two-cut system when no nitrogen was used. Applications of nitrogen reduce the crude protein content under the two-cut harvest system below that of the unfertilized meadow.

More extensive research by Willhite and Rouse has shown that the production increases reported in table 3 cannot be maintained in all years or under all conditions. Length of growing season and average temperature during the growing season influence the results obtained under the two-cut system. These experiments were made where the frost-free period averaged 52 days with an average July temperature of 61.5°. At an experimental area in the South Park of Colorado, the two-cut system produced less hay than the single system. This experimental area averaged 38 frost-free days per season during the experiments. The two-cut system produced 22.3 percent, or 0.47 ton per acre, less hay than the single-cut system at this location (table 4).

Table 4. - Influence of elevation and growing season on hay production, Colorado experimental areas, specified periods, 1950-56

Season and area	Elevation	Frost-free days 1/	Production per acre		Difference	Aftermath 2/
			Two-cut harvest	Single-cut harvest		
	Feet	Number	Tons	Tons	Tons	Percent
South Park 1955-56---	9,250	38	1.64	2.11	-0.47	22.3
Blackstock 1950-55---	7,694	52	2.69	2.56	.13	38.9
Hayden 1955-56---	6,337	85	3.56	2.90	.66	48.0

1/ During the period of the experiments.
2/ Usable growth after harvest of hay under the two-cut system.

Willhite, F. M. and Rouse, H. K. Colorado Mountain Meadow Annual Reports, 1951 and 1956. Fort Collins, U.S. Agricultural Research Service, Soil and Water Conservation Branch. (Mimeographed.)

On the Blackstock plots, the second or aftermath harvest of hay under the two-cut system produced 38.9 percent of the total production, or 1.05 tons per acre, whereas in South Park, the comparative figures were 22.3 percent and 0.36 ton per acre.

Under the two-cut system near Hayden, Colo., average production per acre for 1955-56 was 3.56 tons. Of this amount, 48 percent, or 1.71 tons, was obtained from the second cutting. During the trial period, the frost-free season averaged 85 days. The frost-free period and the production indicated for Hayden, Colo., are not typical of the mountain meadow areas of the State. This experimental area is located at the lower limits of the meadow area. Consequently, its average summer temperature and growing season are considerably above the average in other areas of this kind.

The relationship between growing season, total production, and percentage of total production from the second cutting is summarized in table 4. The two-cut system of harvesting does not show favorable results at elevations above 7,000 feet if volume of hay only is considered. At the South Park location, the two-cut system reduced production on the average by 0.47 ton per acre. At the Blackstock location, the increase was only 0.13 ton per acre. This increase involved harvesting each acre twice, and the added production did not pay for the cost of the second cutting.

Results of the various experiments and observations of experienced ranchers showing the change in production from the no-treatment, single-cut harvest method to the two-cut method with fertilizer added is summarized below: 6/

Item	Fertilizer treatment					
	1	2	3	4	5	6
Change in production---------tons--	0.13	0.35	0.50	0.70	1.10	1.20
Change in protein content---percent--	4.9	4.3	3.9	3.2	3.0	2.9

6/ For fertility treatments used, see footnote 1, table 3.

Under the longer growing seasons, it is probable that when 160 pounds of nitrogen are applied per acre, the two-cut system produces more hay than the single-cut system.

Changing the Composition of the Sward

The proportion of legumes in the sward is important as far as yield and quality of hay are concerned. The legumes normally found in Colorado mountain meadows are alsike and redtop clover. These legumes are adapted to different areas. One area may utilize redtop clover successfully while alsike clover may be almost impossible to establish. In an adjacent area, the opposite might be true.

High yields of mountain meadow hay are usually associated with considerable clover in the sward when little or no commercial nitrogen fertilizer is used. The clover adds to the yield directly, and it is believed that the clover's fixation of nitrogen increases the yield of the grasses in the sward. Intermittent irrigation, reasonably good drainage and, when needed, phosphate fertilizer, are essential to establish and maintain stands of clover.

The term, "clover year," is heard frequently in the mountain meadow areas. It indicates that in that particular year an unusually large part of the hay was clover. The factors that are responsible for good and poor clover years are presently unknown.

A limited amount of research has been done on the seeding of clovers into the sward in Colorado mountain areas. From 1950 to 1953, inclusive, a few trials were made as part of the Blackstock experiments near Gunnison, Colo. A summary of the results of this phase of the experiment is presented in table 5.

The data used for the basis of table 5 were tested by Willhite and Rouse for statistical significance and none was found at the 5-percent level. This is despite the fact that, in each instance, the sods seeded with clover outproduced the native sods. In their test for significance, Willhite and Rouse used all 4 years and all 6 treatments. If the 2 years following seeding are considered alone, then sod seeding by itself under either harvest system, or in conjunction with phosphate fertilizer under the two-cut harvest system, shows a statistically significant increase in production (see appendix table 19). The 2 years following the year of sod seeding are perhaps the only years in which any appreciable increase in production can be expected. Tests for statistical significance show that this was the case in the Blackstock experiments. Sod seeding also increased the crude protein content of the hay slightly.

Table 5. - Yield of hay as affected by seeding legumes on established sods under various fertility treatments, Blackstock experimental area, Colorado, 1950-53

TWO-CUT HARVEST

Type of sod	Yield per acre using fertility treatment 1/						Average yield per acre	Percentage of crude protein in hay
	1	2	3	4	5	6		
	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Percent
Native------	2.56	2.78	2.95	3.15	3.60	3.70	3.12	14.14
Seeded -----	2.80	3.05	3.13	3.31	3.66	3.87	3.30	14.39
Increase---	.24	.27	.18	.16	.06	.17	.18	.25

ONE-CUT HARVEST

Type of sod	1	2	3	4	5	6	Average yield per acre	Percentage of crude protein in hay
Native------	2.42	2.42	2.86	3.14	3.47	3.72	3.00	9.27
Seeded -----	2.58	2.75	2.96	3.21	3.80	3.79	3.18	9.85
Increase---	.16	.33	.10	.07	.33	.07	.18	.58

1/ For fertility treatments used, see footnote 1, table 3.

See Willhite, F. M., and Rouse, H. K., footnote 5, page 12.

This is to be expected as clovers have a higher crude protein content than most grasses.

If a locally adapted legume variety were seeded into an established sod, what production responses might be expected from usual conditions? Using table 5 as the basis, it would be logical to assume the following total increase in hay production over a 4-year period:

Type of harvest	Fertility treatment					
	1	2	3	4	5	6
	Tons	Tons	Tons	Tons	Tons	Tons
Two-cut harvest----	0.95	1.10	0.70	0.65	0.35	0.70
One-cut harvest----	.65	1.30	.40	.30	.30	.30

Practically all of this increase would occur during the 2 years following seeding. At the same time, the average percentage of crude protein would probably be increased by 0.25 percent under the two-cut system of harvesting and 0.60 percent under the one-cut system. Experiments elsewhere tend to support the theory that legumes increase yields of grass or reduce the need for nitrogen fertilizers.

Within 2 or 3 years, the results from experiments presently under way in three areas of Colorado mountain meadows will be available, and a more exact appraisal of legumes in these meadow areas can be made.

The four management techniques discussed may increase the quality and quantity of forage when good intermittent irrigation is practiced. The seeding of legumes into established meadows increases both production and quality of forage. It is the least expensive of the practices considered, but the increases in production resulting from its use are relatively small. Commercial fertilizers, particularly nitrogen, have the greatest potential for increasing the quality and quantity of forage from the meadows. For the most part, the two-cut system of harvesting is a method of increasing the quality and maintaining the production of hay, especially in areas with a relatively long growing season. Time of harvest allows the operator to determine within limits the current quantity and quality of hay. Earlier harvesting, with a meadow cut once, increases the quality and reduces the quantity of hay, but the amount of early or late pasture from an early cut meadow is greater than

that from a meadow harvested on the usual dates.

The average anticipated changes in the production and quality of hay associated with three or four management practices are given in table 6. The highest production per acre and the highest percentage of crude protein is obtained when 600 pounds of nitrogen are used with a two-cut system of harvesting. These data apply to meadows that have relatively good soils, are irrigated under a good intermittent system, and are located in an area that has an average annual growing season of 50 to 55 days. Later economic analysis of cost is based on the data shown in table 6.

COST OF PRODUCING HAY

Before any analysis can be made of the economic feasibility of these management practices, the relationship between the cost of hay harvesting and production per acre needs to be found.

The 1954 Census of Agriculture gives a basis for describing a ranch typical of those in the area. The land components of the typical ranch for the area, which is designated as the Upland Grazing Area, II C-3, are as follows: 7/

Land Use	Acres
Cropland:	
Hay	200
Grain	10
Irrigated pasture	75
Nonirrigated pasture	20
Not harvested or pasture	10
Total	315
Noncropland pasture	35
Other:	
Rangeland	1,670
Waste	40
Total	1,710
Total land area	2,060

7/ U. S. Bureau of the Census, 1954 Census of Agriculture, vol. 1, Part 29.

Table 6. - Estimated changes in production and quality of hay, by specified management practices

YIELD PER ACRE

Method of harvesting	Increases resulting from using fertility treatment - 1/					
	1	2	3	4	5	6
	Tons	Tons	Tons	Tons	Tons	Tons
Single-cut:						
Native sod ---	0	2/ 0.10	0.51	0.79	1.03	1.11
Seeded sod ---	0.16	.33	.54	.79	3/ 1.03	---
Two-cut:						
Native sod ---	.14	.36	.53	.73	1.18	1.55
Seeded sod ---	.28	.63	.71	.89	1.24	---

PERCENTAGE CHANGE IN CRUDE PROTEIN CONTENT

	Percent	Percent	Percent	Percent	Percent	Percent
Single-cut:						
Native sod ---	0	.2	-1.0	-1.0	0	3.2
Seeded sod ---	.5	.5	-.9	-1.0	0	---
Two-cut:						
Native sod ---	4.9	4.3	3.9	3.2	3.0	4.7
Seeded sod ---	4.5	4.6	3.8	3.6	3.6	---

1/ For fertility treatments used, see footnote 1, table 3.

2/ Corrected for discrepancy: Table 2 shows an increase of 0.18 ton per acre, while other work has indicated no increase in production. Probably, the difference is due to the level of P_2O_5 in the soil.

3/ Corrected for discrepancy: Table 3 indicates that a two-cut harvest will increase production by 0.13 ton per acre. Later work by Willhite indicates that production here should not exceed that of native sod receiving 160 pounds of nitrogen.

Willhite, F. M., and Rouse, H. K. Colorado Mountain Meadow Annual Reports, 1952, 1953, and 1954. Fort Collins, U. S. Agricultural Research Service, Soil and Water Conservation Branch. (Mimeographed.)

The average value of 2,060 acres of farmland with improvements was $70,102, or $34.03 per acre. This ranch is typical of irrigated ranches on which approximately 85 percent of the meadowland is found. The typical ranch has approximately 200 acres of hay meadows. This acreage is used as the basis for cost analysis.

Fixed Costs

A large part of the total cost of producing hay is fixed, that is, regardless of whether the production per acre is 1 ton or 3, these costs are about the same. Items included under fixed costs are:

(1) Depreciation and interest on the investment in machinery, machine sheds and stackyards, and housing for hired help;

(2) Interest on the investment in meadowland and its improvements (this does not include other land);

(3) Taxes;

(4) Maintenance costs of ditches and fences on meadowland.

Depreciation on machinery is the only item included in the fixed costs that varies appreciably as production per acre changes. In reality, this variation is insignificant because most of the depreciation on equipment is accounted for by obsolescence and age.

Ranchers with 200 acres of hay meadow have about $5,115 worth of equipment. Of this amount, $3,305, or $16.50 per acre, is invested in equipment for producing twine-tied hay (table 7). The remainder, or $1,810, is invested in machinery for other purposes. Compared with the value of production per acre, this investment in machinery per acre of meadow is relatively high. Average meadowland is valued at $150.00 per acre. Therefore, the average rancher has $166.50 invested in land and machinery per acre of hay meadow.

Table 7. - Value and depreciation of machinery and equipment used to produce hay on a typical mountain meadow ranch, Colorado

Type of equipment (1)	Model 1/ (2)	Cost new 1/ (3)	Useful life 1/ (4)	Annual depreciation 2/ (5)	Percentage of total use for haying 1/ (6)	Depreciation for haying 3/ (7)	Computed value 1957: Total (8)	Computed value 1957: For haying (9)
	Year	Dollars	Years	Dollars	Percent	Dollars	Dollars	Dollars
Tractor	1946	245	15	63	75	40	315	235
Tractor	1953	1,650	15	110	50	55	1,210	605
Mower	1948	300	10	30	100	30	30	30
Mower	1952	300	10	30	100	30	180	180
Rake, S. D.	1954	430	10	43	100	43	300	300
Rake, dump	1948	150	15	10	100	10	70	70
Baler, twine	1953	2,200	10	220	100	220	1,320	1,320
Baler, loader	1953	300	15	20	100	20	220	220
Slip	1954	100	10	10	100	10	70	70
Slip	1953	100	10	10	100	10	60	60
Truck	1952	2,000	10	200	10	20	800	80
Jeep	1950	1,800	10	180	25	45	540	135
Total	---	9,575	---	926	---	540	5,115	3,305
Total machinery per acre of meadow	---	---	---	---	---	2.67	---	16.52

1/ Based on records of mountain meadow ranches obtained in 1956 and 1957.
2/ Based on straight-line depreciation for the years of useful life.
3/ These figures represent the percentage of use in haying (col. 6) multiplied by annual depreciation (col. 5) to obtain the part of the annual depreciation that should be charged against haying.

Using conventional interest rates 8/ for the area, the fixed interest cost per acre of hay meadow is:

Land	$150.00 x .05 =	$7.50
Machinery	16.50 x .06 =	.99
Total		$8.49

For an operator who is in debt, interest is a fixed cash cost. For an operator who is free of debt, interest is an opportunity cost. That is, if the latter had not invested his money in land and machinery, he could receive interest by loaning the money.

A part of the depreciation and interest on the investment in such fixed-cost items as houses for hired labor and machine sheds were included in the costs of producing hay.

The other fixed cost, taxes, varied considerably among areas in Colorado. In 1957, real estate taxes paid per acre of meadowland and its share of the ranch improvements varied from $1.31 to $4.41 per acre. Taxes per acre of meadowland averaged $2.00 for those ranches surveyed.

Fixed costs chargeable against hay production on typical mountain meadow ranch with 200 acres of hay meadow total $3,135.00 or $15.68 per acre annually (table 8). These costs remain nearly constant whether the meadow produces 1 ton of hay per acre or 2. If production per acre could be doubled, the fixed per acre cost would be divided among twice as many tons of hay. To the operator, this means that even if it cost $15.86 to double his production, it would be justified because 1 acre would produce the same tonnage that two produced.

Variable Costs

Variable costs associated with production of hay include such items as machinery repair, gas and oil, labor, and twine. Costs of fertilizer and other improved management practices are not included in this section, even though they are variable costs. They are analyzed later. Included here are only the variable costs that result from changes in production not those that cause changes in production.

8/ Most ranchers pay 5-percent interest on their real-estate mortgages, but 6-percent interest for operating capital and for money used in buying machinery. These are the rates used in this analysis.

Table 8. - Annual cost of producing twine-baled hay with the single-cut system on a typical 200-acre meadow with production averaging 2 tons per acre

Item	Total cost	Cost per ton	Percentage of total costs
	Dollars	Dollars	Percent
Fixed costs:			
Taxes	400	1.00	8.0
Depreciation on:			
Machinery	533	1.33	---
Buildings and sheds	120	.30	---
Stackyards	12	.03	---
Total depreciation	665	1.66	13.3
Interest on investment:			
Value of meadows at 5 percent 1/	1,500	3.75	---
Value of sheds and buildings at 5 percent 2/	160	.40	---
Stackyards	12	.03	---
Machinery at 6 percent	198	.50	---
Total interest on investment	1,870	4.68	37.5
Maintenance of ditch system and fences	200	.50	4.0
Total fixed costs	3,135	7.84	62.8
Variable costs:			
Repairs on machinery	188	.47	3.8
Gas, oil, and grease	187	.47	3.7
Twine	221	.55	4.4
Hired labor:			
Irrigation	120	.30	---
Hay harvesting	480	1.24	---
Meals during hay harvesting	75	.19	---
Insurance on hired labor	13	.03	---
Total hired labor	688	1.76	13.8
Family labor:			
Irrigation	230	.58	---
Hay harvesting	342	.86	---
Total value of family labor	572	1.44	11.5
Total variable costs	1,856	4.69	37.2
Grand total	4,991	12.53	100.0

1/ Includes the value of the irrigation system on the meadow and fences around the meadow.
2/ Only the proportionate share chargeable to hay is included.

Variable costs except those for twine are rather "sticky", that is, their rate of change is not proportionate to the accompanying change in production. For instance, there is no apparent increase in the time required to mow an acre of meadowland producing 2.50 tons when compared with one producing 1.25 tons. Also, the raking time is only slightly greater. It takes significantly more time to bale and stack the hay from meadowland producing the higher yield, but it does not take twice as long. In general, costs of such items as gas, oil, and repair, which accompany these operations, follow a similar pattern.

With changes in the yield of hay, variable costs per acre change considerably less proportionately than does production. This is because the same acreage must be covered with the various implements, regardless of the yield, and except for baling and stacking, lower-yielding hay allows for no substantial increase in the speed by which the machinery can cover an acre of land.

To illustrate this point, the estimated labor required to harvest 200 acres of typical meadowland with different yields per acre are:

Item	Yield at -	
	1.25 tons per acre	2.50 tons per acre
	Man-hours	Man-hours
Mowing	136	136
Raking	111	113
Baling	161	202
Stacking	207	248
Total	615	699
Labor per acre	3.08	3.50
Tons harvested	(250)	(500)
Labor per ton	2.46	1.40

As the yield increases (within the range of production cited), the efficiency of labor and machinery used in harvesting increases substantially. While production per acre increased 100 percent, labor and machinery use increased only 13.7 percent.

Irrigation costs are not necessarily related to production. They vary from year to year, depending on the irrigation program, availability of irrigation water, need for irrigation, and so on. No doubt, a good job of

irrigating a meadow will produce more hay than a poor job and may cost more, but this is not a part of the present problem; it is assumed that a comparable job of irrigation is done.

The other major item under variable costs is the cost of twine. For all practical purposes, this cost is determined by the number of tons baled. A rancher who buys a large rather than a small lot of twine can make certain savings. But when these savings are computed on a per ton basis, the difference is very small.

The estimated costs of producing 400 tons of hay - 2 tons per acre from 200 acres of meadow on a typical Colorado mountain meadow ranch - are \$4,991.00, or \$12.53 per ton (table 8).

Table 8 shows the basic data on costs, but adjustments must be made for yields other than 2 tons per acre. As yields vary, the ratio between fixed and variable costs changes. For example, costs per ton are estimated to be \$14 with a yield of 1.75 tons and as low as \$10 with a yield of 2.5 tons, assuming that no changes in practices and costs are required to obtain the higher yield (table 9).

Table 9. - Percentage distribution between fixed and variable costs in hay production, and average cost per ton at specified levels of production with one cutting, on a 200-acre meadow

Production per acre (tons)	Percentage of total costs that are -		Average cost per ton
	Fixed	Variable	
	Percent	Percent	Dollars
1.75	63.7	36.3	14.06
2.00	62.8	37.2	12.53
2.25	62.0	38.0	11.24
2.50	61.1	38.9	10.26

Based on time and cost records of 14 Colorado ranchers for year 1957.

Costs for Twice-Cut Meadows

One management practice considered is that of cutting hay meadows twice a year. What effect does this have on average cost of production? The

effect is more difficult to determine than the average cost per ton on a single-cut basis as experience with the two-cut method is limited.

Cutting the meadows twice affects very little the total fixed costs of producing hay. The only fixed cost that might be increased is depreciation of machinery. The fact that machinery must cover 200 acres twice instead of once will influence its useful life to some extent. However, obsolesence and aging of machinery is relatively more important in these areas because of the low annual use of the machines. The probable increase in depreciation would not exceed 10 percent.

One other fixed cost item that probably increases somewhat is maintenance of the ditch system. A two-cut harvesting system damages field ditches more than the one-cut system and may entail some additional maintenance on ditches and laterals. The cost of the increased maintenance of ditches and the probable increase in depreciation do not exceed $100 annually. This estimate is used here. It amounts to an increase of approximately 3.2 percent in total fixed costs.

Changes in variable costs between one and two-cut systems are easier to estimate. They are about the same as under the single-cut harvest with comparable yields per cutting.

It has been estimated that on a single-cut basis, it costs $12.48 to produce a ton of hay from a 200-acre meadow when production per acre averages 2 tons. In order to produce hay for approximately the same cost per ton under a two-cut system, production would need to be at the rate of 2.49 tons per acre. With production per acre at 2.5 tons for both cuttings, the cost per ton under a two-cut harvesting system is estimated at $12.34 (table 10). Therefore, with single-cut hay averaging 2 tons per acre, the two-cut system must increase production per acre by 0.5 tons per acre or more, if the cost per ton is to be reduced. The increase in production necessary to compensate for the increased cost of an additional cutting varies from 0.34 ton per acre when the single-cut production is 1.50 tons per acre, to 0.60 ton per acre when the single-cut production is 2.40 tons per acre (fig. 4).

HAY COST ANALYSIS

This section deals with the effects of management practices on the cost of producing hay. The four management practices are not treated separately because a least-cost position for hay of given quality may involve combining two or more of the practices under consideration. For simplicity, hays with

Table 10. - Annual cost of producing twine-baled hay with the two-cut system on a typical 200-acre meadow with production averaging 2.5 tons per acre

Item	Total cost	Cost per ton	Percentage of total costs
	Dollars	Dollars	Percent
Fixed costs:			
Taxes	400	0.80	6.5
Depreciation on:			
Machinery 1/	586	1.17	---
Buildings and sheds	120	.24	---
Stackyards	12	.02	---
Total depreciation	718	1.43	11.6
Interest on investment:			
Value of meadows at 5 percent 2/	1,500	3.00	---
Value of sheds and buildings at 5 percent 3/	160	.32	---
Stackyards	12	.02	---
Machinery at 6 percent 1/	198	.40	---
Total interest on investment	1,870	3.74	30.3
Maintenance of ditch system and fences	247	.49	4.0
Total fixed costs	3,235	6.46	52.4
Variable costs:			
Repairs on machinery	278	.56	4.5
Gas, oil, and grease	311	.62	5.0
Twine	276	.55	4.5
Hired labor:			
Irrigation	160	.32	---
Hay harvesting	872	1.74	---
Meals during hay harvesting	136	.27	---
Insurance on hired labor	23	.05	---
Total hired labor	1,191	2.38	19.3
Family labor:			
Irrigation	280	.56	---
Hay harvesting	605	1.21	---
Total value of family labor	885	1.77	14.3
Total variable costs	2,941	5.88	47.6
Grand total	6,176	12.34	100.0

1/ Based on table 7.

2/ This value includes the value of the irrigation system for the meadows and the fences aroun the meadows.

3/ Only a proportionate share of the total value is included here.

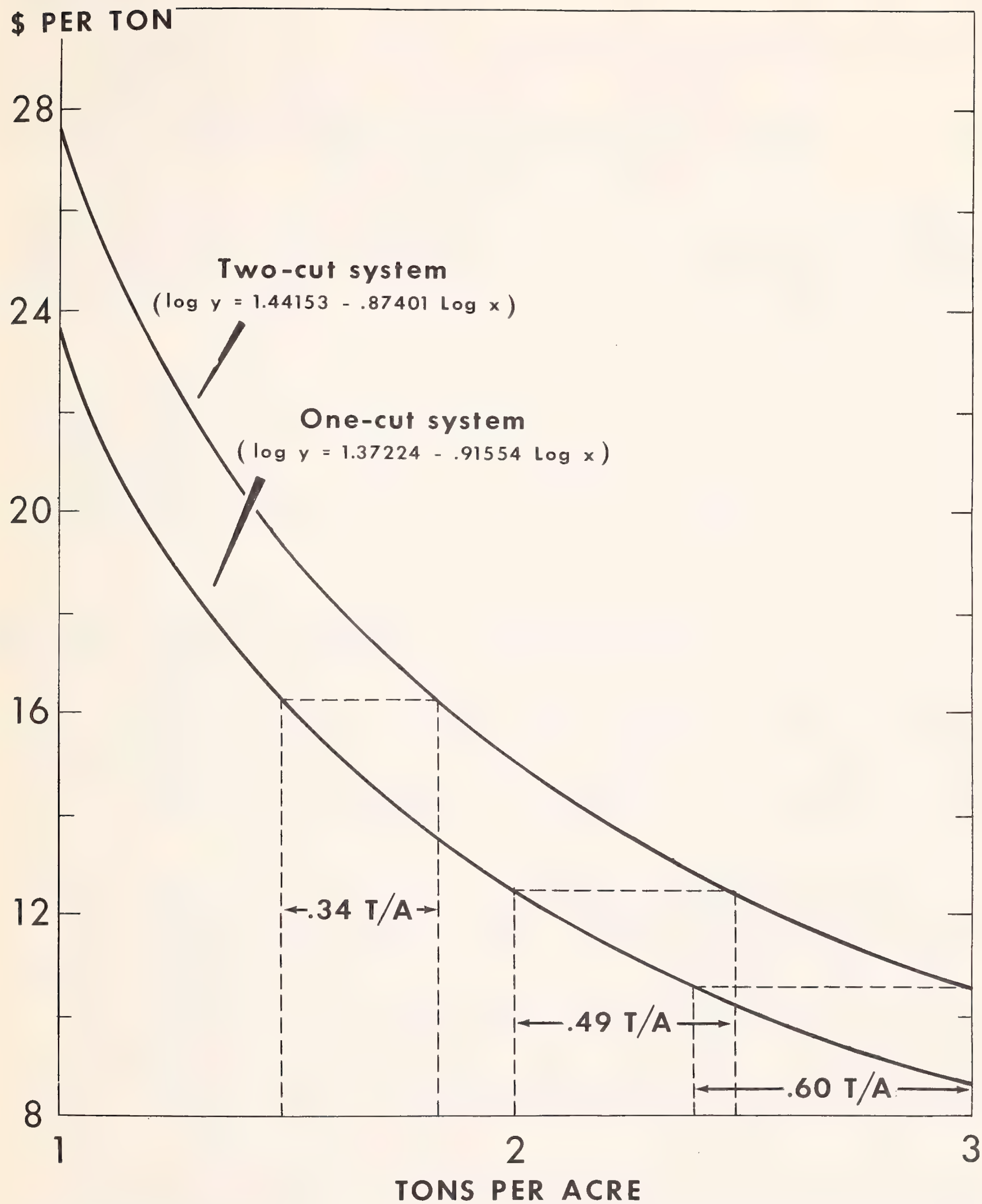

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Figure 4. Average cost per ton of producing and harvesting twine-baled hay under a one-cut and two-cut system, on a typical 200-acre meadow.

the following crude protein content are considered:

8.0 to 9.0 percent, basic feed for pregnant cows;
10 to 12.5 percent, basic feed for weaner calves;
15 to 17.5 percent, as supplement feed.

Commercial nitrogen fertilizer has the greatest potential for increasing the quality and quantity of forage produced from the meadows. The analysis, therefore, begins with this management practice and compares other practices or combinations of practices with results obtained from applications of nitrogen fertilizer.

Hay can be produced at least average cost per ton when no nitrogen is applied. The data in table 11 show that the application of nitrogen increases the yield of hay, but that the cost per ton is greater than the average cost of hay not receiving nitrogen. This does not necessarily mean that application of nitrogen is unprofitable under all conditions, but rather that it increases the average cost of producing hay.

What difference in costs, production, and quality of hay would be expected if phosphate fertilizer were applied instead of nitrogen fertilizer? Application of 200 pounds of P_2O_5 increases production from 2.08 (O treatment) to 2.18 tons per acre and increases the crude protein content slightly (table 12). If the phosphate cost $18 and was effective over a 5-year period, the increase in production would cost $36 per ton of increase for fertilizer alone. Table 12 shows the effect of this management practice on average cost per ton and on the cost of producing an additional ton of hay by this method.

The same table indicates changes in costs expected under a one or two-cut system when the composition of the sward is changed by planting legumes in the sod, using phosphate fertilizer, and combining these practices. The three practices considered here are limited, in that additional inputs do not increase the anticipated production. The phosphate intake cannot be increased unless some other practice, such as nitrogen fertilizer, is added. It is impracticable to seed more than a given number of pounds of legume seed into the sod during a given year. It might be profitable to seed legumes the second or third year, but data on this practice are not available.

Based on the information presented in tables 11 and 12, hays with crude protein content up to 10.5 percent can be obtained most economically by following normal management practices or seeding adapted legumes into the present sod under a single-cut system. If a 15 - to 17.5 - percent protein hay is desired, application of liberal amounts of nitrogen (more than 320 pounds per acre) would be necessary under a single-cut system.

Table 11. - Nitrogen and harvesting costs for hay production, typical 200-acre meadow

Nitrogen per acre	Production		Cost of production				Increase in total cost	Increase in total production	Average cost per ton of increase 4/	Average crude protein content
	Per acre 1/	Total	Nitro-gen 2/	Other	Total 3/	Average cost				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Tons	Tons	Dollars	Dollars	Dollars	Dollars	Dollars	Tons	Dollars	Percent
None	2.08	416	0	5,013	5,013	12.05	0	---	0	10.1
40 pounds	2.59	518	1,200	5,107	6,307	12.18	1,294	102	12.69	9.1
80 pounds	2.87	574	2,400	5,155	7,555	13.16	1,248	56	22.29	9.1
120 pounds	3.02	604	3,600	5,174	8,774	14.53	1,219	30	40.63	9.6
160 pounds	3.11	622	4,800	5,187	9,987	16.06	1,213	18	67.39	10.1
200 pounds	3.16	632	6,000	5,194	11,194	17.71	1,207	10	120.70	11.6
240 pounds	3.19	638	7,200	5,198	12,398	19.44	1,204	6	200.67	13.2
320 pounds	3.21	642	9,600	5,200	14,800	23.06	2,402	4	600.50	14.3
640 pounds	3.22	644	19,200	5,202	24,402	37.89	9,602	2	4,801.00	16.2

1/ Production responses as shown in the calculated yield column of table 2.

2/ Cost of nitrogen applied was figured at $0.15 per pound.

3/ Based on average cost per ton curve Log y = 1.37224 - .91554 Log x, developed in conjunction with table 8 and figure 4.

4/ Cost per ton calculated by dividing increase in total production (col. 9) into increase in total cost (col. 8).

Table 12. - Effects of specified management practices on the average cost of producing hay, cost of producing the additional hay, and their effects on the crude protein content in hay, 200 acre meadow 1/

SINGLE-CUT HARVEST

Management practice 2/	Production: Per acre 3/	Production: Total	Crude protein content 3/	Cost of production: Practice 4/	Cost of production: Other 5/	Cost of production: Total	Average cost per ton	Additional hay production: Increase in total production cost 6/	Additional hay production: Increase in total production 6/	Average cost per ton of increase 6/
	Tons	Tons	Percent	Dollars	Dollars	Dollars	Dollars	Dollars	Tons	Dollars
1	2.08	416	10.1	0	5,013	5,013	12.05	0	0	0
2	2.18	436	10.3	828	5,034	5,862	13.44	849	20	42.45
3	2.24	448	10.6	330	5,044	5,374	12.00	361	32	11.28
2, 3	2.41	482	10.6	1,158	5,076	6,234	12.93	1,221	66	18.50

TWO-CUT HARVEST

Management practice 2/	Production: Per acre 3/	Production: Total	Crude protein content 3/	Cost of production: Practice 4/	Cost of production: Other 5/	Cost of production: Total	Average cost per ton	Additional hay production: Increase in total production cost 6/	Additional hay production: Increase in total production 6/	Average cost per ton of increase 6/
1	2.22	444	15.0	7/	6,114	6,114	13.77	1,101	28	39.32
2	2.44	488	14.4	828	6,185	7,013	14.37	2,000	72	27.78
3	2.38	472	14.6	330	6,160	6,490	13.75	1,477	56	26.38
2, 3	2.71	542	14.7	1,158	6,269	7,427	13.70	2,404	126	19.08
4	2.61	522	14.0	1,200	6,238	7,438	14.25	2,425	106	22.88
5	2.81	562	13.3	2,400	6,294	8,694	15.47	8/ 1,256	8/ 40	8/ 31.40
6	3.26	652	13.1	4,800	6,416	11,216	17.20	8/ 2,522	8/ 90	8/ 28.02
7	3.63	726	14.8	7,200	6,505	13,705	18.88	8/ 2,489	8/ 74	8/ 34.64
8	4.12	824	18.0	9,600	6,608	16,208	19.67	8/ 2,520	8/ 98	8/ 25.74
9	4.91	982	20.1	19,200	6,756	25,956	26.43	8/ 9,748	8/ 158	8/ 61.70

1/ All comparisons are based on the difference between the particular practice in question and the standard ranch practice - single-cut, unfertilized meadows with no supplemental legume seeding.

2/ Management practices: 1 - the present average meadow-management practice; 2 - the application of 200 pounds of P_2O_5 every 5 years; 3 - legumes seeded into the existing sod every 2 years; 2, 3 - the combination of 2 and 3; 4 - the annual application of 40 pounds of available nitrogen annually; 5 - 80 pounds; 6 - 160 pounds; 7 - 240 pounds; 8 - 320 pounds; and 9 - 640 pounds of available nitrogen annually.

3/ Based on changes in production given in table 6.

4/ Costs were calculated on the basis of \$0.15 per pound of nitrogen applied, \$0.09 per pound P_2O_5 applied, and \$3.00 for seeding sod every 2 years.

5/ Costs of producing and harvesting hay were based on formulas developed under hay-harvesting-costs section, fig. 4.

6/ All changes, except as indicated, were calculated by deducting the quantities shown for 1 under the single-cut harvest system, the usual ranch practice except as indicated.

7/ In reality, the cost of this practice is included in cost of harvesting.

8/ The increase shown in total cost and the increase in production are based on the production ever and above that obtained from a smaller application of nitrogen (marginal). Average cost per ton of increase was obtained by dividing the increased cost by the comparable increase in tons.

Using comparable practices, when the two-cut system is used, the average cost per ton is greater than under the single-cut system, but the crude protein content is higher. If an operator wants to be certain that he will have some hay in which the crude protein content exceeds 10. 5 percent, the two-cut system provides the surest method of obtaining it. The two-cut harvest with phosphates used on sod seeded to legumes is the most efficient method of obtaining high-protein hay.

VALUE OF HIGH-PROTEIN HAY

The basic criteria used in determining the value of high-protein hay follow:

> Weaner calves should be wintered to gain between 0. 50 and 1. 0 pounds per day in order to utilize effectively the feed from the following summer's pasture. The value of high-protein hay, when fed as a supplement to weaner calves to obtain this desired gain, cannot exceed the cost of purchased commercial supplements that produce the same winter ratios to gain.

How many pounds of a given quality (crude protein) hay is equal in feeding value to a given quantity of a substitute ration? To find the economic value of superhay, the cost of buying some quantity of such feed as cottonseed cake, which can be replaced nutritionally by a given quantity of superhay was established. This method of determining the value of superhay establishes a higher than average economic value to the rancher. The method does not permit determination of its value through use, that is, the value of the additional pounds of weight added to the animals fed or their offspring when sold in the marketplace.

One of the first questions to be answered is, "Can animals utilize economically all the protein available in 'superhay'?" Morrison's feeding standards indicate that, if the quality of the feed is considerably above these standards, additional gains will be made by the animals fed, but at a relatively high cost per unit of gain. 9/ These standards also throw some light on the conditions under which superhay is more valuable than ordinary hay. If the feed does not meet the following minimum quality or its equivalent, superhay may be more valuable than ordinary hay, or if the feeds exceed these standards to

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9/ Morrison, F. B. Feeds and Feeding. A Handbook for the Student and Stockman. Ed. 21, pp.776-822, 1148-1149. Ithaca, New York. 1948.

any great extent, uneconomical gains may be obtained:

1. A 1,000-pound pregnant beef cow should receive daily 19.1 pounds of hay averaging at least 6.5 percent crude protein.

2. When 1,000-pound beef cows are nursing calves less than 4 months old, they should receive 28.0 pounds of hay daily in which the crude protein content averages at least 7.8 percent.

3. Calves between 400 and 550 pounds should receive daily approximately 11.7 pounds of hay with a crude protein content of 10.2 percent in order to gain 0.75 to 1.00 pound per day. 10/

The various feeding trials conducted by Willhite, Rouse, and associates were concentrated primarily in the area of requirement 3. The conclusions of these workers substantiate Morrison's standards. For instance, heifer calves on feeding trials conducted at Gunnison, Colo., gained an average of 1.03 pounds per day on a daily ration of 11.81 pounds of hay containing 10.1 percent crude protein.

Analysis of hays grown on 20 different ranches from 1950 to 1954 showed that unfertilized hay averaged 9.47 percent crude protein and ranged from 6.25 to 16.43 percent. When 100 pounds of available nitrogen per acre were applied, the crude protein content averaged 9.17 percent and varied from 6.78 to 19.64 percent. Hay produced without nitrogen on 18 of the 20 ranches equaled or exceeded the minimum requirements for the breeding herd. When 100 pounds of available nitrogen were applied, hay produced on 16 of these ranches exceeded the requirements for the breeding herd. 11/

10/ A fourth requirement that could be examined might be stated as follows: When it is desired to have young cattle gain faster than condition No. 3, hay of higher quality will be desirable to increase the protein and TDN intake of the animal. For our purposes, the fourth requirement will not be considered because it is essentially a feeding program designed for slaughter cattle and not within the scope of this publication.

11/ Colorado Agricultural Experiment Station. Mountain Meadow Improvement. Gen. Ser. Paper 615. Fort Collins. 1955.

The following analysis of the value of superhay is based on requirement 3. In order to gain 0.75 to 1 pound per day, calves weighing between 400 and 550 pounds should receive approximately 11.7 pounds of hay with a crude protein content of 10.2 percent. On this basis, the values determined here are higher than the average value assignable to superhay because of the method used.

A practical question at this point is, "What is the most economical nutritional level, or winter gain, for weaner calves when one takes into consideration the following summer gains on range or pastures"? Enough research work has been done on this to permit generalization. It is generally conceded that calves must be fed sparingly in winter so they will not gain more than 0.50 to 1 pound per day in order to obtain the most economical gains the following summer from nonirrigated pastures. 12/ Kincaid, et al (1945), and Potter and Withycombe (1926) have presented results to indicate that for each pound calves gain during the winter feeding period, the gain during the grazing period will be from 0.42 to 0.58 pound less. However, Ruby, et al (1948), has found that increased winter gains resulted in increased total gains, despite the negative correlation existing between winter and summer gains.

Heinemann and Van Keuren 13/ found that there was no significant difference in the overall rate of gain between calves on medium and high winter nutritional levels. In this instance, nutritional levels refer to the protein level, and not the amount of TDN's available. The calves on the medium

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12/ Black, W. H. Wintering Beef Cattle in the Appalachian Region. U. S. Dept. Agr. Cir. 408, 12 pp., illus. 1927. Connell, W. E., Wheeler, S. S., and Tom, R. C. The Effect of Winter Supplementation on Subsequent Gains of Beef Steers on Grass and in the Fattening Lot. Jour. Anim. Sci. 7: 430-433. 1948. Kincaid, C. M., Litton, G. W., and Hunt, R. E. Some Factors That Influence the Production of Steers From Pasture. Jour. Anim. Sci. 4: 164-173. 1945. Mott, G. O., Smith, R. E., McVey, W. M., and Beeson, W. M. Grazing Trials With Beef Cattle at Miller-Purdue Memorial Farm. Ind. (Purdue) Agr. Expt. Sta. Bul. 581, 16 pp. 1952. Potter, E. L., and Withycombe, R. Wintering Stock Steers. Oreg. Agr. Expt. Sta. Bul 224, 15 pp., illus. 1926. Ruby, E. S., Blunn, C. T., Brouse, E. M., and Baker, M. L. Relation of Initial Weights and Subsequent Gains of Weanling Calves. Jour. Anim. Sci. 7: 279-282. 1948. Sheets, E. W. Influence of Winter Rations on the Growth of Steers on Pasture. U. S. Dept. Agr. Cir. 166, 11 pp., illus. 1921.

13/ Heinemann, W. W., and Van Keuren, R. W. The Effect of Wintering Plane of Nutrition on Subsequent Gains of Beef Yearling Steers on Irrigated Pastures. Jour. Anim. Sci. 15(4): 1097-1102. 1956.

level gained 1.01 pounds per hay during the winter, while those on the high level averaged 1.29 pounds (the difference was not statistically significant). When the gains for the winter period and the period on summer grazing on irrigated pasture were averaged, the medium level average gain was 1.46 pounds and the high level 1.59 pounds per hay (table 13). The difference was not statistically significant.

On weaner calves, the effect of high nutritional levels of winter feeding is insignificant when compared with medium levels. But there is a significant difference between low levels on the one hand, and medium and high levels on the other. Usually, a medium level of wintering calves is most desirable, and an average winter rate of gain of 1 pound per day is a practical goal.

Feeding trials at Gunnison, Colo., conducted jointly by the Farm Economics Research Division, Agricultural Research Service, and the Gunnison County Feeding Research Corporation (a group of local ranchers who have contributed cattle, time, and money to the research program), have thrown some light on the substitution ratios of the feeds in question and their values within the desirable rates of gain mentioned (table 14).

There was no significant difference in the rate of gain as between heifers fed cottonseed pellets and those fed superhay to supplement hay of poor quality. The slight difference in results could easily be accounted for by inherent differences between lots of heifers. Each lot ate almost identical amounts of low-protein hay per day, 11.91 pounds for lot 2, and 11.87 pounds for lot 3. The basic hay ration contained only 6.5 percent crude protein. If the rates of gain are the same and the basic intake of hay is the same, it must be concluded that the effectiveness of the supplements fed will be the same under both conditions.

The supplement fed daily to lot 2 was 0.5 pound of 41 percent cottonseed pellets and the supplement fed to lot 3 was 1.18 pounds of chopped 17.4 percent crude protein hay. The cottonseed pellets for the experiment were bought for \$88 a ton, which meant that the daily cost of the supplement fed lot 2 was \$0.022 per animal. As 1.18 pounds of 17.4 percent superhay in feedlot 3 was as effective as the 0.5 pound of 4.1 percent cottonseed pellets fed lot 2, the value of the superhay used must also be worth \$0.022. If this is the case, then the value of 17.4 percent crude protein hay is \$37.29 per ton when 41 percent pellets sell for \$88 per ton.

The price of the pellets used in the feeding trial is above the average price paid for pellets of like type in most years. Therefore, the calculated value of the superhay is also above what it would be on the average. The average price of 41 percent pellets is approximately \$80 a ton, and if this is used as

Table 13. - Effects of winter nutritional levels on rates of gain during winter feeding, subsequent grazing on irrigated pasture, and feedlot gain

Wintering level 1/	Average gains during - Winter feeding 2/ Daily	Winter feeding 2/ Total	Pasture grazing 2/ Daily	Pasture grazing 2/ Total	Winter and pasture Daily	Winter and pasture Total	Feedlot performance 3/ Daily	Feedlot performance 3/ Total	All feedings Daily	All feedings Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
High	1.29	200	1.89	292	1.59	492	2.23	120	1.68	612
Medium	1.01	157	1.91	296	1.46	453	2.23	126	1.57	579
Low	.33	51	2.45	380	1.39	431	1.96	99	1.47	530

1/ Wintering level indicates the protein level of the feed.
2/ Feeding period 155 days.
3/ Average feeding periods: High - 53.8 days; medium - 65.6 days; and low - 50.6 days. These steers were fed until they attained the grade of "good."

See Heinemann, W. W., and Van Keuren, R. W., footnote 13, page 35.

Table 14. - Results per animal of selected feeding trials on heifer calves, Gunnison, Colo.

Lot	Ration	Average per animal - Beginning weight	Ending weight	Gain	Gain per day	Hay consumed 1/ Per day	Hay consumed 1/ Per pound gained	Crude protein consumed per day
		Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
1 2/	3/	426	470	44	0.36	11.90	32.84	0.77
2 2/	0.5 lbs. 41 percent cottonseed pellets 3/	430	550	120	1.00	11.91	11.91	.98
3 2/	1.18 lbs. 17.4 percent super-hay 3/	433	547	114	.95	11.87	12.49	.98
4 4/	10.1 percent crude protein hay	407	508	101	1.03	11.81	11.51	1.19

1/ Net consumption of hay fed free choice.
2/ Willhite, F. M., and Rouse, H. K. Colorado Mountain Meadow Annual Reports, 1956. Page 28. Fort Collins, U. S. Agricultural Research Service Soil and Water Conservation Branch (Mimeographed.)
3/ Lots 1, 2, and 3 fed 6.5 percent crude protein hay in addition to supplement indicated.
4/ Gunnison County Feeding Research Corporation, Seventh Annual Visitors' Day, Ser. Paper 7. 1957 (Mimeographed.)

the cost, then 0.5 pound of 41 percent cottonseed pellets costs \$0.020, and 1.18 pounds of 17.4 percent crude protein hay would be valued at \$0.020, or \$33.90 per ton.

It should be remembered that this value, or relative value, is valid only when the basic feed is 6.5 percent crude protein hay. If the basic feed is higher in crude protein, the relative value of the superhay used as a supplement will be lower than the \$33.90 indicated.

In the year following the feeding trials of 1956-57, lot 4 in table 14 was fed 11.81 pounds of 10.1 percent crude protein hay and its average daily rate of gain for a 98-day period was 1.03 pounds. As daily rates of gain between lots 2, 3, and 4 were so nearly the same, it must be concluded that there is no significant difference in the nutritional value of each ration. The real economic values of the rations are approximately equal. Therefore:

11.9 pounds of 6.5 percent crude protein hay plus 0.5 pounds of 41 percent cottonseed pellets.....

equals

11.9 pounds of 6.5 percent crude protein hay plus 1.18 pounds of 17.4 percent crude protein hay.....

equals

11.8 pounds of 10.1 percent crude protein hay

Each of these rations produced daily gains of 1, 0.95, and 1.03 pounds, respectively, which are about the maximum gains ranchers want on weaner calves. Further increases in the quality of the ration to obtain greater gains are likely to be uneconomical except under unusual circumstances. If this is true, then the feeding of either superhay or 41 percent pellets is uneconomical when the basic ration for weaner heifers provides sufficient quantities of 10.1 percent crude protein hay. This means essentially that when equivalent lots of calves are receiving 10.1 percent protein hay, the value of 17.4 percent hay approaches the value of 10.1 percent hay. Hay with a crude protein content of 10.1 percent is within the range of what is considered to be average good-quality hay for sale and the long-time normal price of this type of hay is valued at \$20 per ton. Therefore, when the superhay is fed with hay of this quality, it cannot be valued appreciably above \$20 per ton.

The value of superhay to a rancher therefore varies inversely as the quality of other components of the ration varies. When fed to weaner calves

whose basic ration consists of 8 percent hay, the value of 17.4 percent hay is between $33.90 and $20.00 per ton, on the average. An approximation of this relationship is shown in figure 5, which indicates that when 8.5 percent hay is fed as the basic hay and 17.4 percent hay is fed as a supplement, the value of the latter as a supplement is $26.10 per ton.

There may be some question as to whether the relationships shown in figure 5 should be represented by straight lines. Data are not adequate to permit determination of whether the relationship is linear or curvilinear. Nevertheless, calculated values derived from the straight line will deviate little from that of the proper curve under the conditions are set forth.

Estimates were made also as to the relative value of 20 percent, 15 percent, and 12.5 percent crude protein hay when used as a supplement in feeding weaner calves. The three estimates used the same cost for 41 percent protein cottonseed cake and baled hay of good quality, that is, $80 and $20 per ton, respectively.

The value of superhay as a supplemental feed probably is not directly proportional to its crude protein content. As a general rule, in other feeds, the higher the crude protein content the more digestible is the crude protein in the feed. It may be assumed that this is true for hay because no evidence to the contrary can be shown. If the crude protein content of hay is increased by 10 percent, its feeding value is increased by something more than 10 percent, or if it is decreased by 10 percent, its feeding value is decreased by more than 10 percent. This has been taken into account in figure 5 and table 15. Although the evaluation used in figure 5 is not exact, it gives a basis for evaluating superhay that is more logical than the use of straight percentage figures.

Table 15. - Estimated value per ton of superhay when fed with basic hay of differing quality to weaner calves

Crude protein content of superhay (percent)	Base hay with crude protein content of-					
	6.5 percent	7.5 percent	8.0 percent	8.5 percent	9.5 percent	10.1 percent
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
20.00	39.50	33.80	31.40	28.60	23.40	20.00
17.40	33.90	29.80	27.90	26.10	22.50	20.00
15.00	28.70	26.10	24.90	23.80	21.50	20.00
12.50	23.70	22.60	22.10	21.60	20.70	20.00

Calculated values for superhay when used as a supplement in winter feeding of weaner calves are shown in table 15. These values are based on the feeding of slightly more than 1 pound of superhay with approximately 11 pounds of the basic hay per day per animal. If it were feasible to feed smaller amounts of the supplement hay, that is, less than 1 pound per day, when the crude protein content of the basic hay is higher than 8 percent, the value of superhay would be somewhat higher. The difficulty of feeding less than 1 pound of supplemental hay per day is not insurmountable, but this rate of feeding is impractical. Therefore, these values are based on the lowest practical amount of supplemental hay that can be fed.

It is well to remember also that the real value, or the value through use, of cottonseed cake decreases as the crude protein content of the basic hay

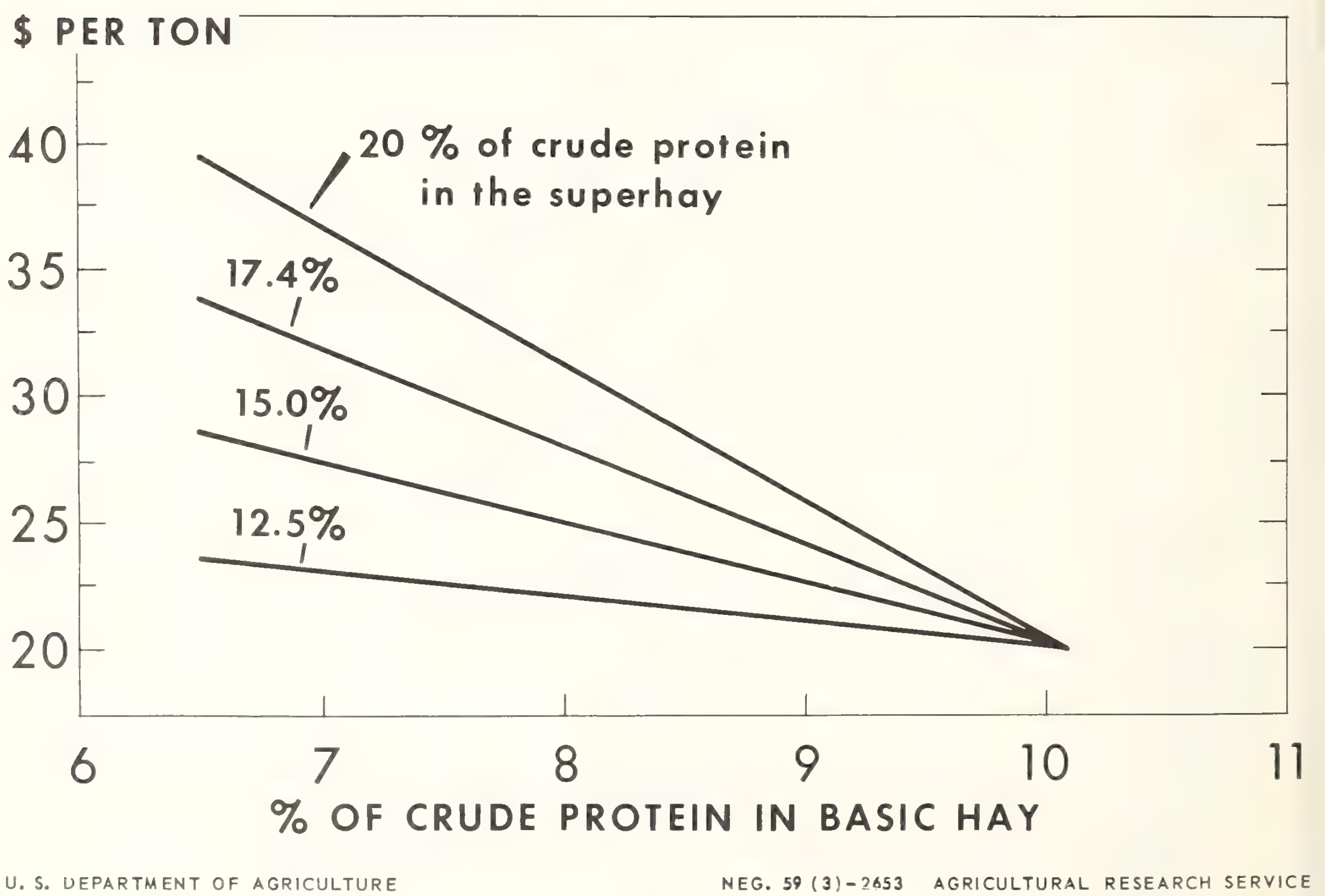

Figure 5. Estimated value of superhays when fed to weaner calves as supplement with various qualities of basic hay (based on 4.1-percent cottonseed cake pellets at $80 a ton and good quality baled hay at $20 a ton).

increases. Its highest value is realized when the crude protein content of the basic hay is low. This is accounted for in figure 5 and table 15 by the reduction in value as the basic hay ration increases in crude protein content.

The values placed on superhay in table 15 indicate its value only when it is fed as a supplement to weaner calves. When the superhay is fed to the pregnant heifers and cows in a breeding herd, its value is considerably less than that shown.

ECONOMIC ANALYSIS OF HAY MANAGEMENT TECHNIQUE

Having established the relative costs of producing hay under various management techniques and having established a maximum value for superhay, the problem is to determine what techniques or management practices will give the greatest input-output ratio and what will set the upper practical limits on each practice (when the input-output ratio is 1). The discussion deals with: (1) Input-output ratios in feeding a breeding herd; (2) input-output ratios in feeding weaner calves; and (3) considerations other than cost of feed.

A breeding herd does not require a ration containing more than 8 percent crude protein but weaner calves require one with at least 10 percent crude protein. For weaners, the ration may be hay with a crude protein content of 10 percent. If the hay contains less than this amount, it can be supplemented with high-protein hay or other feed so that the ration will average 10 percent crude protein.

The data summarized in table 15, together with the cost data in tables 11 and 12, suggest the management practices that might be practical in producing various types of hay. Types of hay are designated as feed for the base herd, feed for weaner calves, and supplemental feed for weaner calves. Alternative management practices and the results to be expected from them are summarized in table 16.

Those practices that show minus values in the "Change in net value of production per acre" in table 16 are practices that are not profitable under the conditions given. Differences in practices showing relatively small plus or minus values (more or less than $1) are not significant. Those with plus or minus changes in value of production per acre greater than $1 are significant. Using this as a criteria, if the change in net value is not $1 per acre or more, from the least cost standpoint, the practice is relatively unfavorable.

Table 16. - Economic feasibility of specified management practices in production of different types of hay, by method of harvest

Harvest and management practice 1/	Production per acre 2/	Crude protein 2/	Gross value 3/	Gross value of preceding practice 4/	Added cost per acre 2/	Change in net value of production per acre
	Tons	Percent	Dollars	Dollars	Dollars	Dollars
FEED FOR MAIN HERD						
Single-cut:						
1	2.08	10.1	41.60	---	---	---
4	2.59	9.1	51.80	41.60	6.50	3.70
5	2.87	9.1	57.40	51.80	6.20	-.60
3	2.24	10.6	44.80	41.60	1.80	1.40
2, 3	2.41	10.6	48.20	44.80	4.30	-1.30
Two-cut:						
2, 3	2.71	14.7	54.20	48.20	6.00	.20
BASE FEED FOR WEANER CALVES						
Two-cut:						
1	2.22	15.0	46.60	41.60	5.50	-.30
2, 3	2.71	14.7	56.90	41.60	12.10	6.30
4	2.61	14.0	54.80	41.60	12.10	1.70
5	2.81	13.3	59.00	54.80	6.30	-2.10
SUPPLEMENTAL FEED FOR WEANER CALVES						
Single-cut:						
7	3.21	13.2	73.10	41.60	37.30	-5.40
Two-cut:						
1	2.22	15.0	55.30	41.60	5.50	8.20
2	2.44	14.4	59.10	55.30	4.50	-.80
3	2.38	14.6	57.80	55.30	1.90	.60
2, 3	2.71	14.7	66.70	55.30	4.70	4.20
4	2.61	14.0	62.10	55.30	6.60	.20
7	3.63	14.8	89.70	62.10	31.30	-3.70
8	4.12	18.0	118.20	89.70	12.50	16.00
9	4.91	20.1	194.40	118.20	48.70	-12.70

1/ For management practice symbols, see footnote 2, table 12.
2/ Based on tables 11 and 12.
3/ Value of hay for "feed for the main herd" at $20 a ton; "base feed for weaner calves" at $21; and supplemental feed for weaner calves" as shown in table 15 (assuming the precentage of crude protein of the weaner calves is 8 percent).
4/ The gross value of the preceding practice reported in this column refers to the practice on which the indicated treatment was added. For example, management practice 4 was added to management practice 1. The additional gross value less the additional costs gives the change in net value shown in the last column.

Feed for Breeding Herd

Hay produced on mountain meadow rarely has a crude protein content of less than 8 percent. Instances in which the crude protein content is less than this are obvious to ranch operators. This low-quality hay is normally associated with damage from moisture or from improper harvesting. Normally, the protein content of hay is not a problem in feed used by the breeding herd. The problem is one of obtaining the needed quantity at least cost.

As noted in the cost of hay analysis, only one of the four management techniques - that of seeding legumes in sod - will reduce the average cost of hay produced. This method reduced the average cost only slightly (from $12.05 to $12 per ton). Also it is limited in its application, that is, production per acre cannot be increased much more than 0.16 tons per acre with heavier rates of seeding. If this increase in production is insufficient to meet the hay requirements of a particular ranch, other alternatives will need to be investigated.

Three management practices (table 16) that increased the value of the production were:

(1) Applying 40 pounds of nitrogen on native sod, practice (4);

(2) Seeding legumes into the native sod, practice (3);

(3) The seeding of legumes into the sod, fertilizing with phosphate and using a two-cut harvest system, practice (2, 3).

If hay is valued at $20.00 per ton, which is approximately the longtime normal price in the mountain areas of Colorado, it would be profitable to use any one of these three practices on mountain meadowland under the conditions described. Such practices as (3) and (2, 3) can be expanded very little beyond the rates shown in table 12 because maximum potential increases in yield probably are obtained at these rates. That is, additional applications of phosphate (P_2O_5) or legume seed will not increase the yield further.

However, additional nitrogen beyond the 40 pounds indicated above can be applied profitably. The maximum theoretical profitable rate of nitrogen application is approximately 50 pounds. This rate would give an increase in value of production per acre greater than the increased cost, while higher rates of application would cost more than the change in the value of the production.

Under a single-cut harvest system, applications of nitrogen up to 50 pounds annually or the seeding of legumes into the sod are potentially economical methods of increasing production of hay. This can be said also for sod seeding and phosphate application under the two-cut harvest system.

Which, if any, of these practices should be followed depends on the relative shortage of feed, the local demand for feed, and the availability and amount of meadowland capable of responding properly to the individual practices.

Feed for Weaner Calves

The hay of average quality produced on mountain meadow ranches probably is slightly below the quality desired for weaner calves. No doubt, also, the best hay produced on these ranches is sufficiently high in crude protein to winter weaner calves properly without protein supplements. If a rancher wants to make sure that enough high-protein hay is available to take care of his weaner calves, he may decide to try growing some high-protein hay on part of his meadowland.

If so, what is the most economical way of producing hay having 10.0 to 12.5 percent crude protein? Only hays that have average crude protein contents higher than minimum requirements are considered to be sure that the hay produced will meet the desired specifications under most conditions encountered in hay harvesting.

Normally, when a meadow is harvested twice, the first cutting's percentage of crude protein is less than the weighted average by approximately 1 percent. Therefore, on twice-cut meadows hay produced would need to average at least 11 percent crude protein. The hay from the first cutting would then average 10 and that from the second cutting 12 percent crude protein. Maturity of the species in the sward is the chief determinant of crude protein content. The more mature the species, the more susceptible they are to damage from adverse weather. Hays high in crude protein minimize quality losses during the harvesting period.

Data from table 11 shows that more than 160 pounds of nitrogen must be applied under a single-cut harvest to obtain hay of the desired quality. Ordinarily any hay produced under the two-cut system will average higher in crude protein content than minimum requirements.

Data in tables 12 and 16 show that under a two-cut system, sod seeding plus phosphate fertilizer gives the cheapest increase in yields. The protein content of hay produced in this way averages 14.7 percent, and the average cost per ton for the increased production is $19.08 (table 12). This cost is

slightly less than the usual purchase price of average hay. This production practice appears to be the most economical; if the proper soil and water conditions exist, it should be considered by ranchers. If a rancher does not have meadowland suited to these practices, either the light application of nitrogen fertilizer (40 to 50 pounds annually) under the two-cut system of harvesting, or the two-cut system alone will provide the least expensive alternative for producing high-protein hay.

A rancher who has only a limited acreage with soil profile and irrigation facilities suited to these various management techniques may want to raise a very high-protein superhay to feed as a supplement. In this way, he could feed weaner calves 11 pounds of basic ration hay with a protein content averaging between 8 and 9 percent and approximately 1 pound hay with a crude protein content of 14.5 percent or more per day.

Several feasible alternative practices are open to ranch operators in producing superhay to be used as a supplement (table 16). All of the alternatives involve a two-cut system, either alone or with nitrogen fertilizer. High rates of nitrogen application show the greatest potential return. Very high rates of nitrogen application have a residual effect on the following year's production, thus making this practice more favorable than appears in the data shown. Offsetting this, however, is the increased risk because of higher cash inputs.

One factor that might also be considered is that under normal ranch operations, the acreage set aside for superhay does not need to be large. For example, 100 weaner calves receiving 8 percent crude protein hay as their base feed would require for supplemental feed the production from 3.75 acres of two-cut native meadow. If the two-cut harvest method were used with an application of 320 pounds of nitrogen per acre, production from only 2 acres would be needed. Therefore, the acreage that might be used to produce superhay for supplemental feeding on a typical ranch would be small.

Considerations Other Than Cost of Feed

The rancher is especially interested in the number of cow-units 14/ he can winter with the production from his meadowland under different management practices and in the costs of his winter feed (table 17).

14/ 100 cow-units for a cow-calf ranch are based on the feed needed to winter 100 cows and 20 head of weaner heifers or, for a cow-yearling ranch, the feed needed to winter 100 cows and 90 weaners.

Table 17. - Costs of winter feed per cow unit, by specified management practices, typical Colorado mountain meadow ranch with 200 acres of good hay meadow

COW-YEARLING RANCH

Practice followed in providing - 1/			Cow units 2/	Cost of winter feed per cow unit
Ration for breeding herd	Ration for weaners: Base feed	Ration for weaners: Supplement		
			Number	Dollars
Normal	Normal	41 percent cake	169	32.64
Normal	Seeding plus P_2O_5 3/	None	183	31.02
Normal	160 lbs. N 3/	None	192	33.94
Normal	Normal	Seeding plus P_2O_5 3/	165	30.70
Seeding	Seeding plus P_2O_5 3/	None	192	31.01
Seeding	160 lbs. N 3/	None	202	33.87
Seeding plus P_2O_5 3/	Seeding plus P_2O_5 3/	Seeding plus P_2O_5 3/	190	32.92
40 lbs. N	Seeding plus P_2O_5 3/	None	213	31.31
40 lbs. N	40 lbs. N	160 lbs. N 3/	205	31.36

COW-CALF RANCH

Normal	Normal	41 percent cake	227	22.70
Normal	Seeding plus P_2O_5 3/	None	232	22.35
Normal	160 lbs. N 3/	None	236	23.00
Normal	Normal	Seeding plus P_2O_5 3/	226	22.73
Seeding	Seeding plus P_2O_5 3/	None	249	22.30
Seeding	160 lbs. N 3/	None	252	22.90
Seeding plus P_2O_5 3/	Seeding plus P_2O_5 3/	Seeding plus P_2O_5 3/	261	23.90
40 lbs. N	Seeding plus P_2O_5 3/	None	284	22.60
40 lbs. N	40 lbs. N	160 lbs. N 3/	281	22.55

1/ Management practices are indicated under each appropriate ration column. Normal refers to hay that is handled under the typical single-cut late-harvest method normally practiced by ranchers. Seeding denotes the seeding of adapted legumes into the sod in alternate years. When pounds of nitrogen are indicated this means annual application.

2/ Cow units for cow-yearling ranch includes feed for 100 cows and 90 weaner calves; for cow-calf unit, 100 cows and 20 weaner calves.

3/ These hays are harvested twice annually.

The differences among the various practices in cost of winter feed per cow-unit are relatively small. Perhaps a result more important to the ranch operator is that the various practices will permit him to produce various quantities of feed and thereby potentially vary numbers of cow-units in winter. In the long run, the average ranch operator must balance his winter feed (that produced, purchased, and sold) with the spring, summer, and fall forage he has available. Therefore, an operator who has excess winter feed, which he usually sells, is interested only in practices that will produce additional feed at less than the price he receives for his hay when it is sold. Other operators who have shortages of winter feed, but who normally can buy sufficient quantities of feed nearby, are interested only in those practices that will produce additional feed at less than the cost of buying it. Operators short of winter relative to summer feed and who have access to limited supplies of purchased feed, may be more interested in increasing the number of cow-units their meadows will "feed" during the winter.

Certain necessary but minor overhead feed requirements were not included in table 17. For example, no feed for bulls or horses was included. While these are relatively minor overhead feed requirements, ranchers must take them into account.

APPENDIX

GUIDE FOR DETERMINING RATE OF APPLICATION OF NITROGEN FERTILIZER TO PRODUCE HAY

As indicated in the analysis of feed for the base herd of cattle, the average Colorado meadow that is amenable to nitrogen application can utilize profitably approximately 50 pounds of available nitrogen. Because very few meadows are average, a relatively simple method of determining the approximate "most profitable rate" is presented.

To determine the most profitable rate, a rancher needs to know three things:

1. The nature of the nitrogen response curve for the meadow or meadow type in the area. This can be obtained by ranchers working with their county agents, or the ranchers can conduct their own nitrogen fertilizer trials;

2. The cost per pound of available nitrogen applied. This can be found by calculating the price of available nitrogen and adding to this the esti-

mated cost of applying it to the meadow;

3. The value of hay at the ranch.

With the answers or approximate answers to these questions, ranchers can then look at table 18 to determine the approximate most profitable rate of nitrogen application.

The method of determining the most profitable rate first requires that the maximum number of pounds of nitrogen per 0.25 ton per acre be determined, based on the cost of nitrogen and the value of hay. Second, using this sum, the point at which this amount of nitrogen increases the yield by approximately 0.25 ton per acre at the right end of the fertilizer response curve must be found. When this is determined, the most profitable rate is the midpoint for the amount that gives this 0.25 ton per acre increase.

This procedure is illustrated by using two different response curves (figure 6). Both curves are based on the data in table 2. Curve "A" is based on data shown for ranch No. 7 and curve "B" is based on data shown for ranch No. 6. Curve "C" is based on the calculated yield from table 2. Under the cost-value conditions used throughout the publication, twine-tied hay valued at $20 per ton and nitrogen applied to the meadow at $0.15 per pound, shows that the maximum amount of nitrogen the rancher can afford to apply to increase production per acre by 0.25 ton is 32 pounds (table 18). Curve "A"

Table 18. - Quantity of nitrogen per acre that will cost the same as the value of 0.25 ton of hay

Value of hay per 0.25 ton (dollars)	Price of nitrogen per pound			
	13 cents	15 cents	17 cents	19 cents
	Pounds	Pounds	Pounds	Pounds
7.50	58	50	44	39
6.25	46	40	35	31
5.00	36	32	28	25
3.75	27	24	21	19

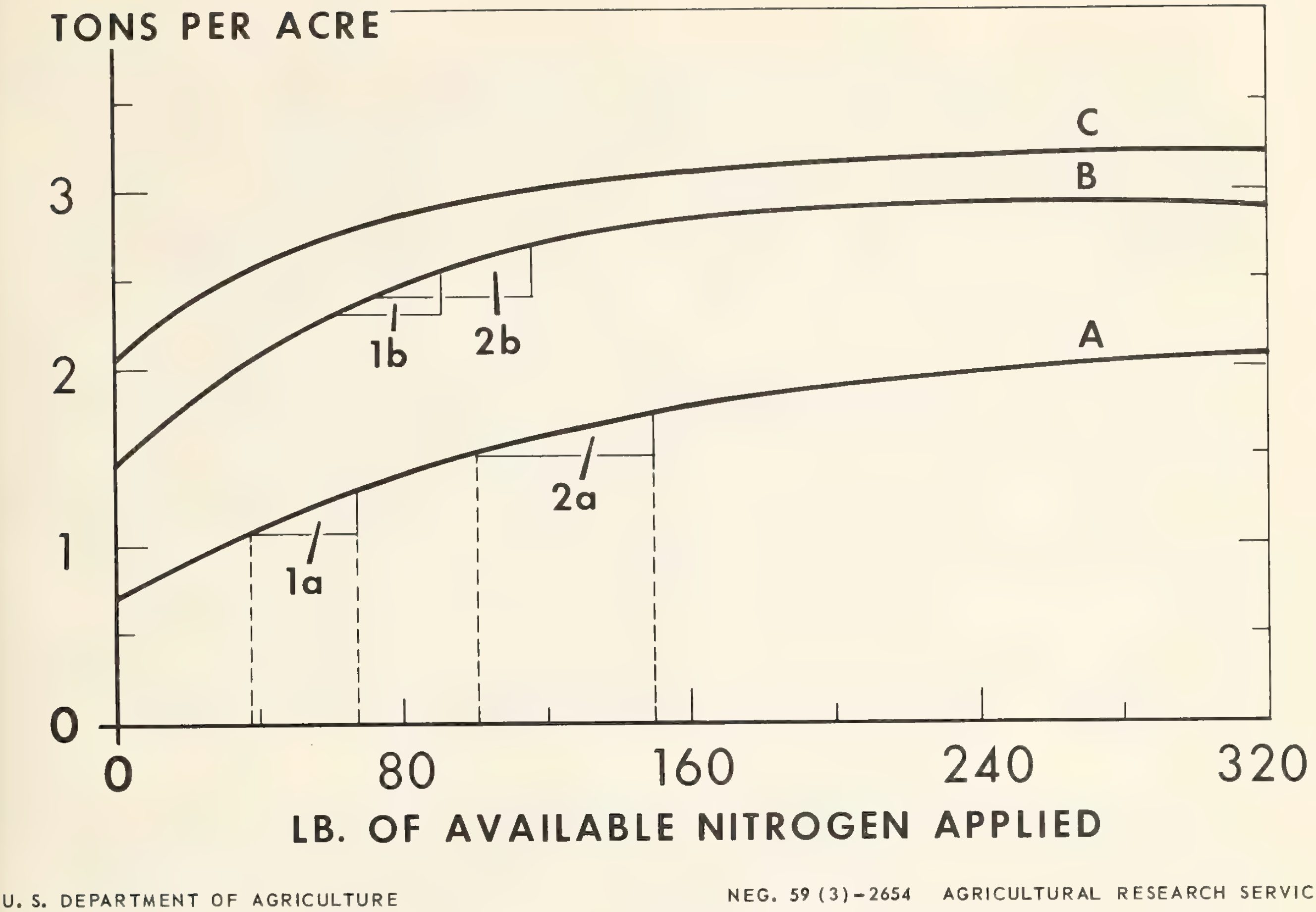

Figure 6. Estimated nitrogen response curves showing relationship between rate of application of nitrogen fertilizer and yield of hay under selected conditions.

(fig. 6) shows that after the first 38 pounds of nitrogen have been applied, an additional application of 32 pounds increases the yield by 0.25 tons. In this instance, the theoretical most profitable rate is halfway between 38 and 70 pounds of nitrogen, or 54 pounds, 15/ and the theoretical production per acre is 1.21 tons.

This method is used also in determining the most profitable rate of nitrogen application based on curve "B", but a different answer is obtained because of the difference in the nature of the meadow's response to nitrogen. In this instance, increasing the application of fertilizer from 60 to 92 pounds (32 pounds) increased production per acre from 2.30 to 2.55 tons per acre, or 0.25 ton. Therefore, the most profitable rate is 76 pounds per acre (halfway between 60 and 92 pounds).

15/ See pages 50 and 51 for explanation.

If hay were valued at $25 per ton and nitrogen cost $0.13 per pound, more nitrogen could be applied economically. Under these conditions, table 18 indicates that the maximum break-even range is 46 pounds of nitrogen for 0.25 ton per acre increase. On curve "A," under these conditions, the range is as indicated by 2a (104 to 152 pounds of nitrogen): the midpoint is 128 pounds of nitrogen, and production per acre indicated is 1.68 tons. On curve "B," the range is indicated by 2b, nitrogen is indicated at 97 pounds, and production at 2.58 tons per acre.

It may seem strange that in the first instance (hay valued at $20.00 per ton and cost of nitrogen at $0.15 per pound), the most profitable rate of nitrogen application on curve "B" is greater than that on curve "A," while in the second case the reverse is true. This is due to the fact that curve "A" has a more gentle slope - the meadow's response to nitrogen (nitrogen efficiency) is greater at the higher rates of application than in the case of curve "B." At the lower rates of nitrogen application, the response to nitrogen shown by curve "B" is greater, as indicated by the steeper slope of the curve. The point here is that before the most profitable rate can be approximated, a fairly good idea of the nitrogen response curve must be obtained.

This analysis indicates that there is precision in the answers, but in reality there is no such precision. First, it is almost impossible to apply exactly 71, or 171, pounds of nitrogen per acre. Second, even if the exact response curve has been determined for a particular field by field trials over a period of years, there is no assurance that weather, water, and so on, during the current year will be the same as in the years during which the trials were run. Despite these drawbacks, it is to the rancher's advantage to determine the theoretical most profitable rate of nitrogen application for his particular conditions. This gives him the maximum economic rate of application, which is the real foundation of his eventual decision as to "how much nitrigen to apply this year." For this reason, the presentation here has merit.

WHY MIDPOINT IS MORE PROFITABLE THAN FULL APPLICATION RATE

Table 18 indicates that, with 32 pounds of nitrogen per acre applied to a meadow, production of hay must increase by 0.25 ton per acre to allow one break even, if hay is valued at $20 per ton and nitrogen costs $0.15 per pound. Applying this to curve "B," figure 6, we find that if the rate of application of nitrogen is increased from 60 to 92 pounds per acre, the expected increase in production is 0.25 ton per acre. When all costs are considered, this last 0.25 ton increase has just paid for itself and no more. If this section of the curve is blown up and smoothed out, it shows that the

first half of this increased application (from 60 to 76 pounds) increases production much more than the last half (76 to 92 pounds) (fig. 7). The first half increases production by 0. 18 ton per acre and the second half by 0. 07 ton. This means that the second half of the nitrogen application does not produce its proportionate share of the needed increase, 0. 125 ton per acre, and that consequently it costs more than it returns. The first half produces more than its proportionate share and returns more than it costs. This explains the statement that, under these conditions, the most profitable rate is midway between 60 and 92 pounds for curve "B." Theoretically, it might differ slightly from this because of irregularities in the nitrogen response curve, but for practical application it is near enough to the correct theoretical application to be used.

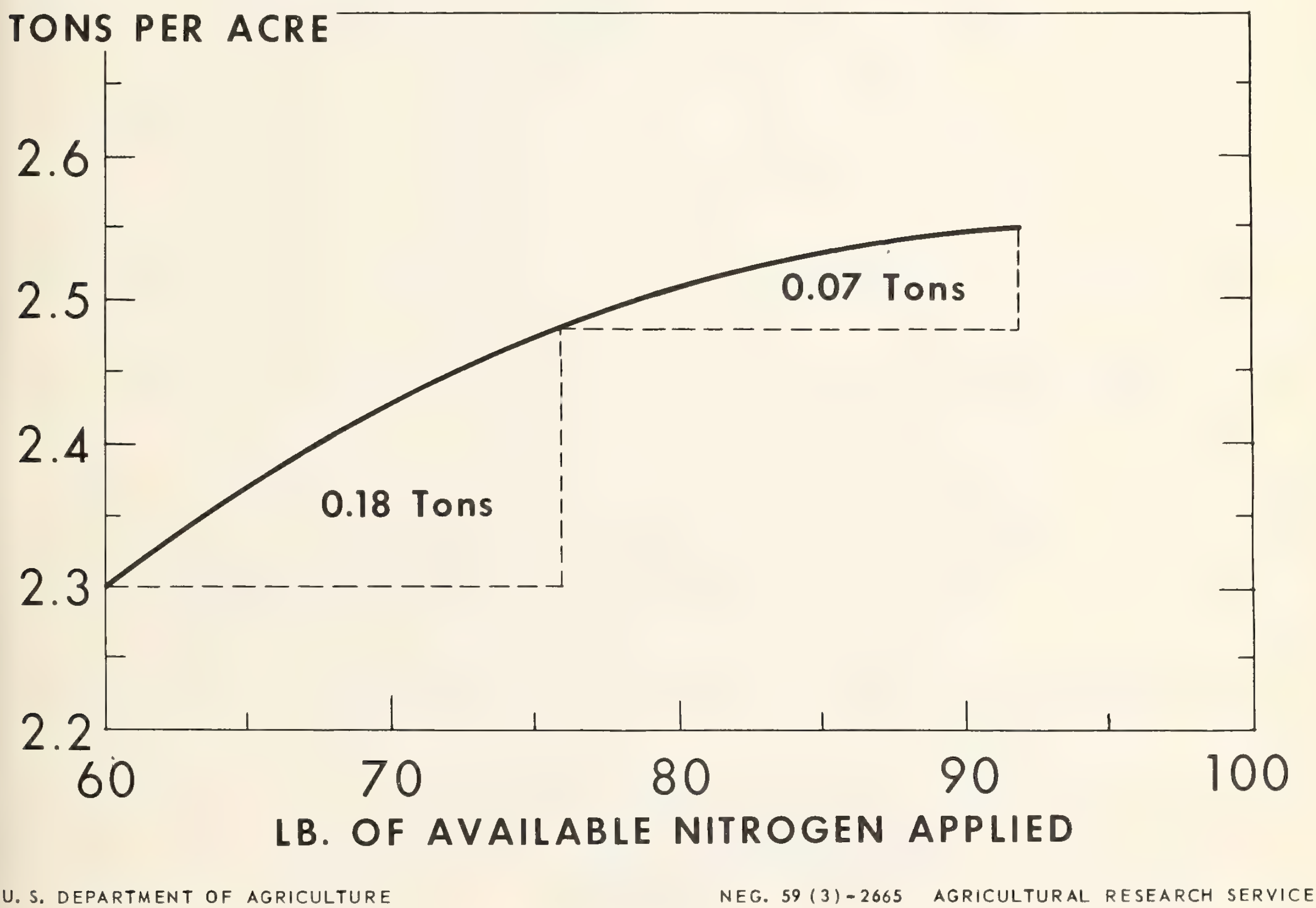

Figure 7. Select section of curve "B" from figure 6.

BASIS OF CALCULATION OF COW-UNITS IN TABLE 19

Certain assumptions were made to calculate the number of cow-units and the feed cost per cow-unit. The assumptions were as follows:

1. A 165-day feeding period

2. Feed required:
   (a) Cows - 20.0 pounds of hay per day
   (b) Weaner calves:
      (1) 11.0 pounds of base hay during entire period
      (2) 1.0 pound of supplemental hay if fed
      (3) 0.5 pound of 41 percent cottonseed cake if fed, valued at $80.00 per ton

3. Costs for each type of hay and production per acre are as indicated in tables 11 and 12.

The example below explains in greater detail how the number of cow-units was determined.

Problem: How many cow-units will a 200-acre hay meadow provide winter feed for, if:

1. The breeding herd receives regular harvested hay?

2. Weaner heifers received hay produced from meadows that are harvested twice on land receiving phosphate fertilizer and the sod has been seeded with legumes?

Basis: How many acres are required to provide feed for 100 cow-units under this management system:

1. 100 cows x 165 days x 20 pounds per day = 330,000 pounds, or 165.00 tons, of hay

$$\frac{\text{165 tons regular hay needed}}{\text{2.08 tons regular hay per acre}} = 79.327 \text{ acre}$$

2. 20 weaners x 165 days x 11 pounds per day = 36,300 pounds, or 18.15 tons

$$\frac{\text{18.15 tons of P+S hay needed}}{\text{2.71 production P+S day per acre}} = 6.697$$

3. Therefore, 100 cow-units need 86.024 acres (79.327 + 6.697) to produce their winter feed

OR

200 acres of hay meadow will provide feed for 232 cow-units under these conditions.

Table 19. - Average annual increases in yield of hay for given fertility practices applied to establish sod seeded with legumes, Blackstock Experimental Area, Colorado 1/

Period	Fertility practice 2/					
	1		2		3	
	Yield difference	Probability level of difference 3/	Yield difference	Probability level of difference 3/	Yield difference	Probability level of difference 3/
	Tons		Tons		Tons	
One-cut harvest:						
All years (1950-53)	0.16	0.60	0.33	0.30	0.54	0.10
Last 3 years (1951-53)	.19	.30	.37	.10	4/ .58	.01
Middle 2 years (1951-52)	5/ .37	.02	.29	.10	.69	.40
Last 2 years (1952-53)	.10	.70	.41	.20	5/ .71	.05
Two-cut harvest:						
All years (1950-53)	.24	.60	.49	.30	.57	.20
Last 3 years (1951-53)	.34	.30	.57	.10	5/ .60	.05
Middle 2 years (1951-52)	5/ .51	.05	4/ .76	.01	.51	.30
Last 2 years (1952-53)	.26	.60	.44	.30	.62	.20

1/ Legumes seeded in 1950.

2/ Fertility treatments are the same as in table 3, that is, (1) indicates no fertilizer, (2) single application of 200 pounds of P_2O_5 in 1950, and (3) annual application of 40 pounds of available nitrogen.

3/ Probabilities based on table 3 of R. A. Fisher and F. Yates, Statistical Tables for Biological, Agricultural and Medical Research, Edinburgh, 1938.

4/ Significant at the 1-percent level.

5/ Significant at the 5-percent level.

See Willhite, F. M., and Rouse, H. K., footnote 5, page 12.

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